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1914: January, February, March, April, September, October, December.
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SUPPLEMENT, No. 3.

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ALFRED J. HENRY, Editor.

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THE SEMIPERMANENT ARIZONA LOW.

By E. A. BEALS.

[Weather Bureau, San Francisco, Calif.]

Although there is a rainy and a wet season in the Pacific States, it is sometimes fair in winter and sometimes it rains in summer. It is the good weather in winter and the bad weather in summer that are so hard to predict, and I believe better work in forecasting summer rains would result from a better understanding of the action of the air over the interior of California and Arizona during the summer months.

In the book entitled "Weather Forecasting in the United States," written by officials of the Weather Bureau and published in 1916, I called attention to the Great California Valley as the place of origin of low-pressure areas that produce some of the summer rains in the North Pacific States. It is my opinion that this center of activity has not been given the study it deserves in forecasting work.

Among the effects of heated air over a definite land area mentioned as being the cause of rainfall is one by Griffith Taylor, who is attached to the Commonwealth Weather Service of Australia. He states:

> The regions of greatest convection are logically more likely to control the supply of lows and of rainfall and storms than the so-called "centers of action."

Mr. Taylor's explanation of his theory can be found in Chapter XVIII of his book entitled "Australian Meteorology," published in 1920. He mentions two convective centers of action in Australia, one in the west-central portion of the State and the other near the north-central portion.

He states:

> Over such centers [of action] * * * there is built up a column or dome of warm ascending turbulent air. * * * The building up of this "dome" increases day by day, until it becomes, as it were, top-heavy. Thereupon an eddy of air buds off—much as the satellites leave the parent—and sails away in the current of upper air drift, which is usually to the east. * * * The chief rains are associated with the satellite lows, which bud off and move to the southeast.

I am in thorough agreement with him in what he calls "the convection-dome hypothesis," whereby it is assumed that strong convection over heated areas produces eddies that later develop into storms of sufficient energy to cause rain; but the Aleutian low-pressure area is, nevertheless, the dominating factor in generating winter storms that affect the Pacific coast of the United States.

However, a number of the storms causing summer rains in the Pacific and Rocky Mountain States, according to my belief, originate over the valley of the lower Colorado River and the great interior Valley of California. The low-pressure areas that have their genesis in this region sometimes move east and cause rains in the Middle West and Eastern States, therefore they are of more than local importance in consequence of their far-reaching effects.

More rain falls from these low-pressure areas in the Pacific and Rocky Mountain States than is shown on the weather map, as all stations reporting by telegraph are located either along the coast, on plateaus, or in valleys, whereas the rainfall is heaviest in the mountains, where there are no stations reporting daily by telegraph.

I myself have seen a cumulus cloud form over an intense conflagration. The base of this cloud was so dense as to indicate that rain might fall from it at any moment. This fire was in a lumber yard covering about an acre of ground, and the cloud was estimated to be about 1,500 meters in height. If intense heat over such a limited area will produce a cloud, a less degree of heat over a larger area might generate eddies in the atmosphere that would develop into low-pressure areas of sufficient intensity to produce rain.

It is asserted that upwelling cold waters in the Pacific Ocean just west of California mark the eastern extension of a so-called permanent high-pressure area. From this high-pressure area come cold northwesterly surface winds of high humidity, so much so that the California coast is bathed in fog during the greater portion of the summer months.

In contrast to this the interior valleys of California and lower Colorado valleys experience temperatures for days at a time above the 100° mark. To the east of these valleys the prevailing summer surface winds are southerly with low humidity.

Thus the conditions are ideal for the formation of eddies in the air adjacent to the Sierra Nevada Mountains, and the only element needed for a full-fledged storm is plenty of moisture. This is usually deficient because the air coming from the ocean is cold, and though loaded to its capacity with moisture can not easily again become saturated when mixed with warmer and drier air till cooled below the dew point by expansion at high elevations.

As a rule eddies that form over the California and lower Colorado valleys do not produce rain until through convection they have accumulated sufficient moisture for this purpose. This they do to a greater extent after moving some distance to the north or east of the place where they are formed.

The charts displayed and marked A, B, C, etc. (figs. 1–2), illustrate the formation and movement of the eddies that apparently separate from the dome of rising air over the California and lower Colorado valleys as a result of a spell of hot weather that began on July 3, 1920. Before examining this specific case, a few general remarks on the subject will perhaps put the matter in a clearer light.

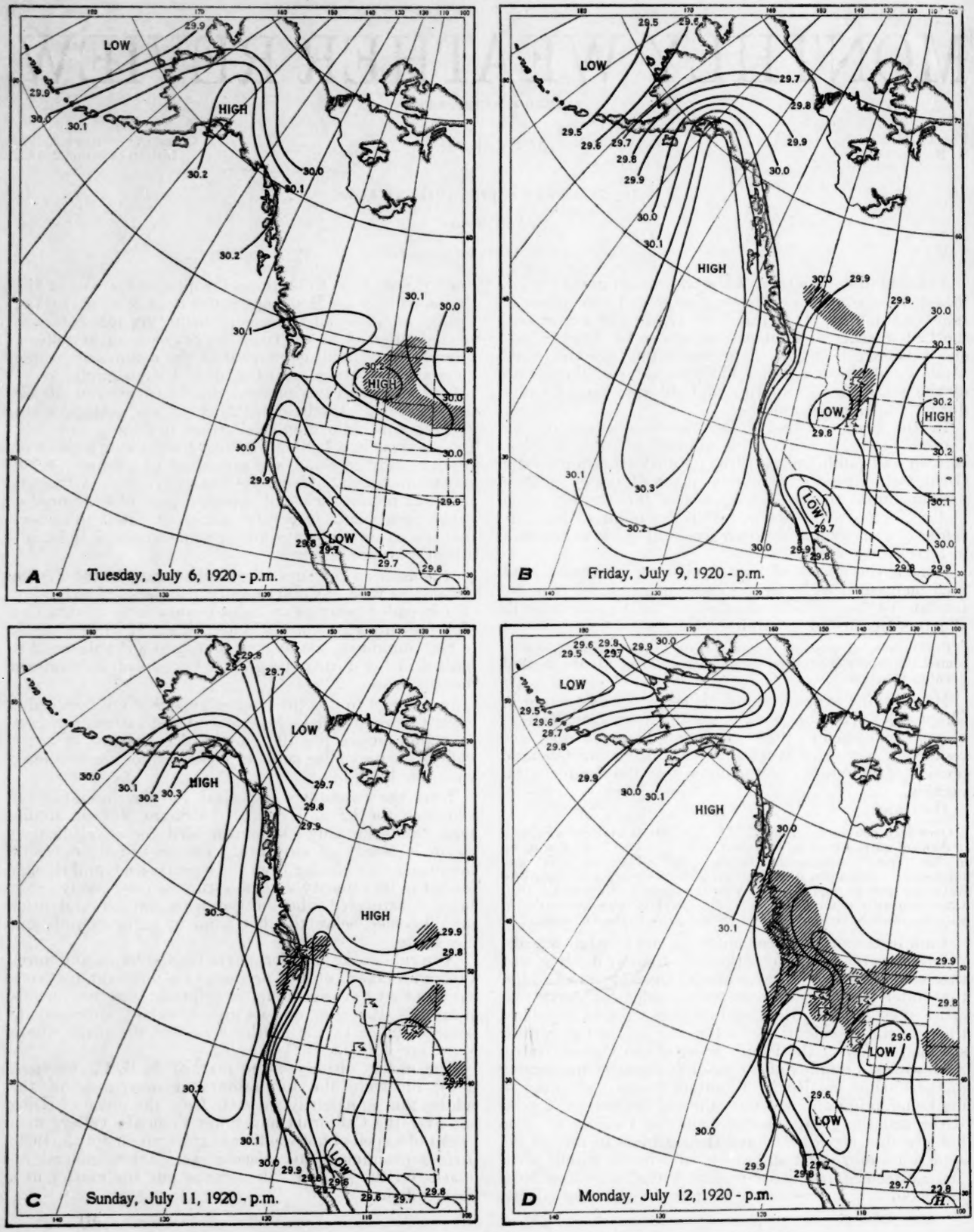


FIG. 1.—Distribution of barometric pressure in western United States and adjacent ocean areas on various dates.

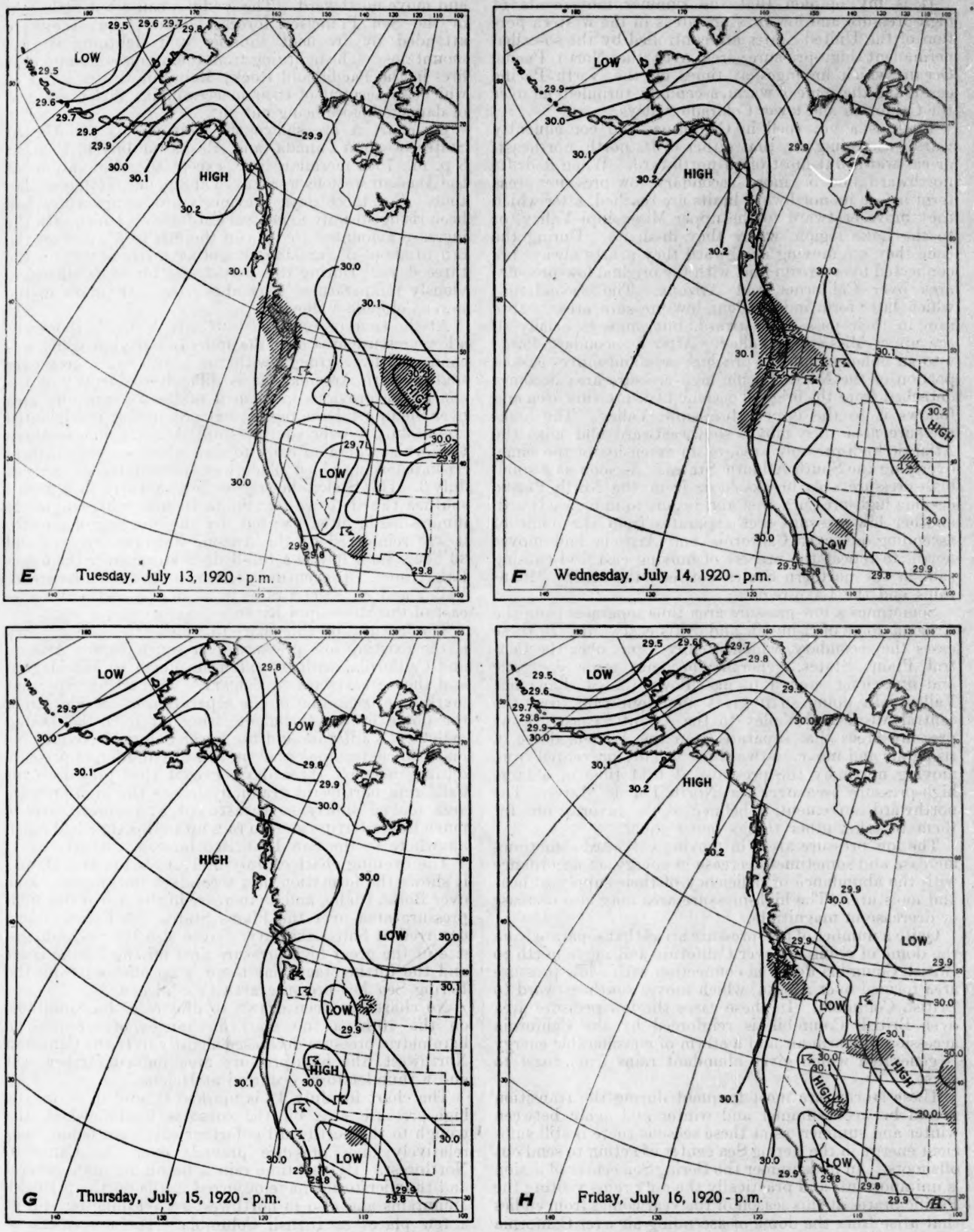


FIG. 2.—Distribution of barometric pressure in western United States and adjacent ocean areas on various dates.

It is my opinion that the summer movements of high-pressure and low-pressure areas in the western portion of the United States are controlled by the so-called permanent high-pressure area over the North Pacific Ocean, which impinges at times on the North Pacific coast, and the dome of warm, ascending, turbulent air over the California and lower Colorado valleys.

First, is a hot spell in California, and consequently warm, ascending air, that either drifts north, northeast, or eastward, but most often northward. When it drifts northward one or more secondary low-pressure areas form before its northward limits are reached, after which they move eastward to the upper Mississippi Valley, or to the Lake region, where they dissipate. During the time they are moving northward they nearly always are connected by a stream line, with the original low-pressure area over California and Arizona. The secondaries, which later form independent low-pressure areas, cause rain in their passage eastward, but more especially in the upper Mississippi Valley. After a secondary forms into an independent low-pressure area and moves east, a portion of the North Pacific high-pressure area becomes detached from the original oceanic high-pressure area and follows it to the upper Mississippi Valley. The high-pressure area then moves southeastward and joins the Atlantic high-pressure area, or an extension of the same, overlying the South Atlantic States. As soon as a small high-pressure area breaks loose from the North Pacific oceanic high-pressure area and begins to move eastward, another low-pressure area separates from the dome of ascending air over California and Arizona and moves north, to repeat the process of moving east and causing rain in the northern States between the Rocky Mountains and the Lake region.

Sometimes a low-pressure area thus separates from the Arizona dome of rising air and drifts eastward. In these cases the secondary, which usually forms over the Central Plains States, generally becomes more energetic and lives long enough to pass down the St. Lawrence Valley. In doing so it gives abundant rain from the central Mississippi Valley to the Atlantic coast. Low-pressure areas that separate from the Arizona dome of rising air and move eastward are usually prevented from moving north by the presence at that time of a large high-pressure area over the North Pacific States. The northward movement, I believe, is the favorite one for them to take, other things being equal.

The low-pressure areas in moving eastward sometimes increase and sometimes decrease in energy, in accordance with the abundance or deficiency of their supply of heat and moisture. The high-pressure area may also increase or decrease in magnitude.

Quite a number of low-pressure areas that separate from the dome of rising air over California and move north to British Columbia do so in connection with a low-pressure area formed over Alaska, which moves southeastward to British Columbia. In these cases the low-pressure area over British Columbia is reinforced by the California accession of warm air and a storm of considerable energy is generated which gives abundant rains from coast to coast.

These storms are most frequent during the transition period between summer and winter and again between winter and summer, as at these seasons there is still sufficient energy in the Bering Sea center of action to send out offshoots. In midsummer the Bering Sea center of action is unimportant, and practically the only rains visiting the Pacific States at this season of the year comes from eddies that arise from the dome of ascending air over California and move northward. These eddies cause but little rain in the San Francisco forecast district, but they are attended by frequent thunder and lightning in the mountains. The lightning from them causes many forest fires in the Pacific and Rocky Mountain States, some of which, on account of their inaccessibility, do a great deal of damage before being put out.

On chart A are shown the isobars over the United States, western Canada, and Alaska on July 6, 1920, at 8 p. m., 75th meridian time, except the observations at the Alaskan stations were taken at 8 p. m., 135th meridian time. For three days previously the temperature had been rising steadily in central California. On the 4th the increase amounted to 10°, on the 5th to 5°, and on the 6th to about 5°, making altogether a rise of 20° for the three days. During this period and for some time previously temperatures were above the 100° mark in the lower Colorado Valley.

At the time represented by Chart A (fig. 1) there was a low-pressure area over the upper Lake region, which was connected by a trough with the low-pressure area over southwestern Arizona. It is difficult to identify on the charts the previous movement of the low-pressure area over the upper Lake region, but presumably it originated about July 1 over southwestern Arizona and southern California, where an eddy formed which moved north to Saskatchewan, which place was reached the morning of July 3. This Saskatchewan low-pressure area then moved southeastward to western South Dakota, where it greatly diminished in intensity; but, by the morning of the 5th, it was reinforced by the Arizona low-pressure area and 36 hours later it was a full-fledged storm over the upper Lake region. It eventually moved down the St. Lawrence Valley and gave good rains in all of the northern States east of the Mississippi River.

The features on this chart to which attention is called is the existing low pressure over southwestern Arizona and California, with its extension north to Washington and thence eastward to Calgary. This is the type that marks the beginning of the separation of an eddy from the dome of the turbulent rising air over the heated valleys of California and the lower Colorado River. No material change took place in this distribution of pressure during the next three days, except that pressure over California northward gradually fell as the high-pressure area moved slowly southeastward and spread over a much larger territory. No rain up to this time had fallen anywhere in the San Francisco forecast district.

The evening chart of July 9, 1920, is marked B, and it shows the formation of a secondary low-pressure area over Boise, Idaho, and an increase in the size of the high-pressure area over the Plains States. A thunderstorm occurred at Salt Lake City. Note also the position and size of the great high-pressure area off the Pacific coast and the further fact that there is no offshoot from the Bering Sea low-pressure area in evidence.

No chart has been drawn to illustrate the conditions on the 10th, as no marked changes occurred. The barometric pressure decreased slightly over the Canadian Northwest, the high-pressure area moved farther east and a thunderstorm occurred at Helena.

The chart for July 11 is marked C, and it shows the high-pressure area off the coast is undiminished, the trough to the northward is farther east than before, and relatively high pressure prevails over the Canadian Northwest. By this time rain is becoming more general and thunderstorms have occurred in the northern Rocky Mountains and also in northwestern Washington and at a few places in British Columbia. The movement of

the trough eastward caused a drop of about 7° or 8° in temperature in the interior of California, while the Arizona temperature remained as high as ever.

Chart D shows the conditions the next day, July 12, and here we have more rain in the North Pacific States and British Columbia, most of which is attended by thunderstorms. The high-pressure area off the Pacific coast has apparently lost energy, and the secondary over southern Idaho has reappeared. There is also evidence of a storm developing over the Bering Sea which may complicate matters should it move southeastward.

On the 13th the conditions are shown on Chart E (fig. 2) and here is seen a development of the high-pressure area which was faintly indicated on Chart C. The low-pressure area over Bering Sea is less pronounced and the consolidation of the southern Idaho low-pressure area with the original low-pressure area over Arizona has taken place. The rain has diminished and most of it fell locally along the North Pacific coast.

The next day, July 14, is represented on Chart F, which is somewhat like Chart A; but with this difference, the barometer is lower in the north and rainfall, which was lacking on Chart A, is quite abundant along the North Pacific coast. Thunderstorms have occurred at Yakima, Spokane, and Kalispell. Temperatures in the interior of California have risen about 8° in consequence of the rearrangement of pressure.

The conditions on the 15th are shown on Chart G, and here is seen a secondary over Idaho, with relatively low pressure over the Canadian Northwest. The high-pressure area has moved east, and the high-pressure area over the ocean is about the same as it was for the last few days. So few reports from the ocean are available that this high-pressure area can not always be definitely located. The rains are light and sporadic. Thunderstorms occurred in the southern portion of California and also at Winnemucca and at Seattle.

The final chart, marked H, shows a general unsettled condition over the Pacific States. Rain has fallen quite generally in Nevada, northern Washington, and western Montana. The eastern high-pressure area is disintegrating, and the relatively low pressure of the day before over the Canadian Northwest has recovered somewhat. This low-pressure area two days later reached the upper Mississippi Valley, and still later passed down the St. Lawrence Valley. In doing so it caused showery conditions in the Lake region and in the North Atlantic States.

Nothing would be accomplished by showing more charts, for they are continually repeating themselves with slight variations all summer long. They give an excellent idea of the difficulties encountered in predicting rain during the summer months in the Pacific States. During the period from July 11 to 16, inclusive, rain fell in nearly all portions of the San Francisco forecast district, and it was evident that it would do so. However, to place this rain geographically for 12-hour intervals was an entirely different matter, and the only thing possible was to make an indefinite forecast for places where it was thought the rain was mostly likely to occur.

Reports from Mexico and a greater number of upper-air observations would undoubtedly be of help in obtaining more definite information regarding the mechanism of the offshoots from what I believe should be called the semipermanent Arizona low. The California part, which first attracted my attention, now seems to be an auxiliary that probably has something to do with directing the movement of the stream lines, or eddies, northward. By taking the northward course they receive additional heat as well as a greater supply of moisture than would be the case if they moved to the northeast or to the east.

DISCUSSION.

By E. H. BOWIE.

With regard to the quotation from Griffith Taylor in the opening of Mr. Beals's article, I would remark that my understanding of this matter is that it has been presented to us quite fully by the late Professor Ferrel in his discussion of the formation of cyclones; in the minds of some, however, convection does not account for the formation of cyclones but has to do with the origin of showers and thunderstorms as observed in the Tropics and other parts of the world.

Doubtless many meteorologists will take exception to the view that in overheated, arid areas there is built up a column, or dome, of warm, ascending, turbulent air as suggested by Taylor. The English idea, if I may so call it, is to the effect that air rises in threadlike streams, not *en masse*, and that between these threadlike streams there will be areas over which air is descending. Hence the sporadic character of thundershowers in regions of strong convection, such as the southeastern part of the United States.

Certainly if heat alone would produce cyclones there should be a considerable number over the far Southwest during the summer, but such is not the case as may be easily seen by reference to MONTHLY WEATHER REVIEW SUPPLEMENT No. 1, Types of Storms of the United States, by Bowie and Weightman. This report shows that for the months of June to September, inclusive, in 21 years but 30 cyclones moved out of the area under discussion, or a little more than 2 per year.

DISCUSSION.

By W. J. HUMPHREYS.

The description of the development of cyclonic storms in the region of southwestern Arizona is both interesting and useful.

It may be remarked with reference to the trough of low pressure which appears to be largely induced by the high temperature of the Arizona and California valleys, that such trough, as indeed all troughs, is unstable and likely to break up into isolated lows or secondaries. This is especially true when the trough is well developed or flanked by a high to the west and another to the east with oppositely directed winds on its two sides.[1]

If there is no precipitation, such a low (secondary) probably will soon be dissipated. With precipitation it may persist for some time and over long distances.

DISCUSSION.

By A. J. HENRY.

Before entering upon a discussion of Mr. Beals's paper it would be helpful to state briefly the several aspects of the paper upon which there is general accord.

Although the author does not specifically state the number of cyclones of the type described he has considered, I think we can accept the count given in Supervising Forecaster Bowie's statement, viz, about 2 per year (in summer).

[1] While this situation may and does arise in the cold season it would fail in the warm months, since high-pressure areas at that time of year seldom, if ever, extend as far south as the lower margin of the Great Basin in Nevada.—EDITOR.

The topographic control of the weather of the Great Valley of California.—Any discussion of the weather of California without a full understanding of the topographic effect upon the weather would be useless and this is our excuse for describing what probably most readers are familiar with. The dominating topographic features of the State are the two mountain ranges, the Sierra Nevada on the east and the Coast Range on the west; between these two mountain systems lies the Great Valley of California broadly open from the Tehachapi on the south to Shasta on the north, a distance of about 400 miles. While the valley may be divided into three parts according to the drainage, yet for our purpose it may be considered as a single geographic unit which, except for the Tehachapi, may be extended southeastward to, and merging into, the valley of the lower Colorado River. Between the Tehachapi and the Colorado is the almost rainless waste known as the Mohave and Colorado Deserts. In the northern half of this waste the surface relief is broken by volcanic hills and low ranges of mountains between which deep salt-covered valleys lie. The Great Valley is, of course, a highly populated region devoted to agriculture, whereas the region southeast of the Tehachapi is, in places, a typical desert waste.

The Weather Bureau has maintained for years a station at Yuma, Ariz., in the lower Colorado River Valley. In drawing isobars and isotherms on the daily weather maps it is customary in summer to connect the lower Colorado Valley and the Great Valley of California by a system of continuous lines. These lines at times follow the contours of the valley and at other times, as may be seen from the figures submitted by Mr. Beals, they extend in a north-south direction over the southern part of the Great Basin. In the summer months, owing to the proximity of the Pacific on the west, both the temperature and pressure gradients between the hot dry interior and the cool, moist coast are very much exaggerated and are artificial in a sense rather than actual by reason of the contrast in the temperature before mentioned. Thus it happens that the barometric gradients of the weather map for California in the months June to September represent a more or less distorted pressure distribution due to the great temperature contrast within the short distance which separates the coast line from the hot interior. It can be easily shown that with initially low pressure in the Great Valley a very slight fall in pressure, such as is associated with cyclonic systems approaching the coast of Washington or Oregon will result in lower pressure in the valley than in adjacent regions both to the west and the east. It is therefore difficult at times to distinguish between real and fictitious LOWS (cyclonic systems). The wind circulation because of the sparseness of the stations is of very little aid in determining whether cyclonic circulation is present or absent.

The thought which most impresses the writer is that only a beginning in this problem has been made. The study of the development of secondaries south of the primary cyclone is one of the major problems which confronts forecasters of the Bureau.

At this point I wish to invite attention to some of the results of sounding-balloon observations made at Santa Catalina Island, off the California coast, by the Weather Bureau in 1913, summarized in this REVIEW for July, 1914, page 410.

Some of the soundings were made on consecutive days and at practically the same hour of the day. The changes in temperature in steps of 1 kilometer have been extracted from that summary and are presented in the table below. For comparison with these data I have copied the daily weather maps for the dates on which consecutive soundings are available (not reproduced).

TABLE 1.—*Twenty-four hour changes in free-air temperature (°C.) from sounding-balloon flights at Santa Catalina Island, Calif.*

Dates.	Kilometers.								
	3	4	5	6	7	8	9	10	11
July 29–30	+9.2	+8.8	+10.0	+9.9	+10.6	+12.7	+13.6	+13.2	+12.0
July 30–31	−5.7	−5.2	−5.3	−7.8	−10.8	−12.7	−11.8	−12.0	−10.1
July 31–Aug. 1	−1.9	−2.2	−0.1	+1.8	+3.1	+5.1	+4.6	+5.6	+4.2
Aug. 1–2	+1.4	+2.7	+1.0	+2.7	+3.1	+1.0	+1.5	−0.5	−2.4
Aug. 2–3	+2.3	+1.0	+0.1	−1.4	−2.6	−2.0	−2.6	+0.3	+2.9

Dates.	Kilometers.							
	12	13	14	15	16	17	18	19
July 29–30	+13.1	+8.5	+7.0	+10.0	+9.9	+8.9	+5.3	+6.0
July 30–31	−8.1	−7.8	−5.4	−6.2	−7.4	−8.8	−5.0	−5.7
July 31–Aug. 1	+2.9	+4.6	+6.9	+4.9	+3.7	+2.6	0.0	−1.2
Aug. 1–2	−5.0	−2.9	−4.3	(?)	(?)	(?)	.....	.....
Aug. 2–3	+4.8	+5.1	−5.1	(?)	(?)	(?)	.....	.....

The remarkable fact shown in Table 1 is the magnitude of the rise in temperature on the 30th as compared with the 29th in all levels up to 19 kilometers. The rise began at the surface and seemed to be at a maximum in the levels between 8 and 12 kilometers. The winds on the 29th in the layers next to the surface were from the NW. The balloon was lost in the clouds at 1,012 meters elevation; its general movement was toward the north. The flight on the following day started in a surface wind from the NE., but soon the winds shifted to SE. and S., being south at 1 kilometer S. 86° W. at 1,184 meters, then backing to S. 42° E. at 1,338 meters, it held for a short time in about that direction and was S. 18° E. at 4,362 meters when the balloon was lost in the clouds. This balloon traveled toward the NNW. 140 kilometers from its starting point and yielded a fine temperature and pressure record. Winds from the SSE. on Santa Catalina Island must have traversed 60 to 70 miles of water surface before reaching the island. If projected still greater distance from the island they must have passed over land in southern California.

On the 31st, the temperature fell rather sharply in practically all levels. The wind on this date was S. 57° E. at 1,000 meters, S. 24° E. at 2,000 meters, and finally at 8,384 meters, where the balloon was lost in the clouds, the wind direction was S. 4° E., from which direction it should have come from a water surface. It is to be noted that with the shifting of the wind into a nearly true southerly direction the temperature fall increased, the greatest fall being recorded at 8 kilometers.

There does not seem to be any obvious relation between the direction of the free-air currents and the temperature changes; on the 29th, 30th, and 31st the former were from the south in the main yet the temperature changes on each date were decidedly different the one from the other. Many more flights will be necessary before tentative conclusions can be reached.

The data of kite flights have shown rather conclusively that the temperature in the free air up to 4 kilometers, and perhaps higher, follows that of the surface with respect to the sense of the change from normal and also in a broader sense which may be stated as follows: Free-air temperatures, up to at least 4 kilometers, correspond to surface temperatures, the more so the less is the free air mixed by the local circulation of cyclones and anticyclones.

From these considerations the air over desert areas should be considered as warmer, level for level, than air over surrounding areas with a vegetative cover. It would seem that the free air over deserts receives a greater increment of heat in the daytime than it loses by radiation at night and that the excess, small though it may be, is cumulative, so that after a time we should expect that free-air currents from the lower Colorado Valley and the Gulf of California would be warm as compared with currents from the Pacific. The former by reason of the lower specific gravity of the air in them can not flow to the westward. The most likely course of the air is therefore in the direction impelled by the pressure gradient. The latter generally indicates a movement toward the north. The sounding balloons liberated on the six successive days, July 29 to August 3, traveled in a northerly direction and the lowest temperature recorded during the flights was experienced on August 3—the last day of the six in which the free-air currents moved as above stated. When flights were resumed on August 5 the free-air winds were from the SSW. and the minimum temperatures were distinctly higher than during the first-named period, although in some of the flights the balloon did not reach so great a height as in the first period. A better comparison, however, would be to use a definite level reached by all of the balloons furnishing useful records up to, say, 14 kilometers. Such a comparison shows that the temperature in southerly winds was on the average 2.7° lower than in westerly winds. The interpretation of this fact is left in some uncertainty, since the southerly winds of the group July 29 to August 3 had more or less easterly components, which might mean that originally they were of continental origin.

Comparison of the data of Table 1 with the weather maps for corresponding dates leads to some interesting suggestions. The distortion of the isobars in the summer months, before mentioned, makes it difficult to determine the probable direction of the free-air winds from surface isobars, but when the pressure distribution over the entire Rocky Mountain and Plateau region is considered there is better agreement between the pressure gradients and the direction of the free-air winds.

Thus on July 28–29 the west-southwest winds above Santa Catalina Island were evidently due to a cyclonic disturbance that was moving eastward over southern Alberta. This disturbance deepened somewhat and moved east-northeast in the next 24 hours, so that by the morning of the 29th the whole of the northern Rocky Mountain region and the upper Missouri Valley were under its influence. On this date an anticyclone began to pass from the ocean to the land over the States of Washington and Oregon.

On the next day, July 30, this anticyclone had advanced inland as far as northwestern Wyoming and the barometer level at its center had risen to 30.20 inches. Coincidently with this movement the temperature in the free air, as shown in Table 1, rose decidedly; pressure in the free air also rose, but fell slightly at the surface and as a result the isobar inclosing the center of low pressure over Arizona is now projected northward to include the Great Valley of California. In other words, from surface indications one would say that the Arizona and California lows have intensified and merged. But if we take the free-air observations under consideration as an index to what occurred over California and Arizona, it is at once seen that the surface indications are no sure guide to what has actually happened in the free air.

On the next day, July 31, the free-air temperature fell about as much as it had risen the day before. The anticyclone by this time had advanced to western Nebraska; its center now stretched to southeastern Idaho as an oval with central pressure of 30.30 inches, a rather unusual anticyclone for the month of July.

With the entry of this anticyclone over the continent the free-air winds which previously had been southwest now became southerly and as the anticyclone advanced to the eastward the winds became SSE.

It is rather significant that the lowest temperature reached in the whole series of sounding-balloon ascensions was on August 3 at a height of 17,428 meters, and that on the previous day an almost equally low temperature was reached at an elevation of 21,302 meters, thus perhaps indicating a slight lowering of the current of cold equatorial air.

The important thought of the paper, as I see it, is the necessity of a further study of the influence of summer North Pacific anticyclones upon the weather of the Rocky Mountain and Plateau region. It is already known that the movement eastward of these anticyclones gives the clue to shower forecasts for western and central Colorado, New Mexico, Arizona, and southern Utah.[2]

[2] Weather Forecasting in the United States, p. 115.

THE PRESSURE DISTRIBUTION AT VARIOUS LEVELS DURING THE PASSAGE OF A CYCLONE ACROSS THE PLATEAU REGION OF THE UNITED STATES.

By C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., August 15, 1922.]

INTRODUCTION.

Barometric reductions in the Plateau.—It is important to ascertain what effects, if any, a mountain range, or lofty plateau, exerts on the meteorological elements of a passing storm. The Plateau region of western United States projects into the atmosphere to an average height of approximately a kilometer and a half above the level of the sea over an area of more than 5,000,000 square kilometers. Situated, as it is, in a position of the greatest strategical importance, from the viewpoint of the forecaster, it is essential that he understand very clearly the relations between the surface weather conditions and the pressure distribution.

The problem is a complex of hypsometric effects, and meteorologists are thoroughly cognizant of the fact that reduction to sea level in the Plateau introduces much that is unreal in the horizontal barometric gradients. Owing to the hypothetical nature of the process, the allowance for fallacious effects is a difficult, if not impossible, task, and it is necessary, therefore, to be content with the knowledge of the presence and mode of origin of these false features.

The differences, however, between the probable distribution of pressure at sea level were the continent removed and the actual distribution at the average level of the Plateau where the weather occurs *do* admit of investigation. These differences arise not through faulty

reduction methods, but through inherent characteristics of the hypsometric relation. In this way alone the pressure distribution, when reduced to a level from 1 to 2 kilometers below the points of observation, may assume a quite different aspect from that at the average level of the observation points themselves. The magnitude of this difference varies with the intensity of the horizontal temperature gradients.

Bigelow, in devising the system of barometric reductions now employed in the United States, attempted to eliminate this hypsometric effect by assigning such values to the mean temperature of the reduction column as would reproduce on the sea-level map the actual distribution of pressure at about 1 kilometer (actually 3,500 feet).[1] In this he was doubtless partially successful. The weakness of his scheme is the assumption that a given surface temperature is *always* associated with the same mean temperature of the fictitious air column, a view that is incompatible with the evidence obtained by means of kites. While we may grant the partial success of the attempt, the frequent want of conformity of wind speed to indicated gradients affords abundant evidence that it is not always satisfactory.

If, then, the sea-level map in this region represents neither the actual distribution of pressure at the average elevation of the Plateau nor the distribution that would occur at sea level were the Plateau removed, we may justly ask why the attempt to reduce to that level is made at all. This reasoning only leads to the long-recognized truth that, having accurate knowledge of the vertical temperature gradients, we could undoubtedly make a more satisfactory weather map by reducing pressure to some level near that of the station. If temperature arguments are somewhat speculative, there is the compensating fact that the distance through which the reduction must be effected is considerably shortened and the resultant pressure error appreciably reduced.

With the purpose of testing the practicability of making such reductions, and, more especially, of ascertaining in what respects the distribution of barometric pressure differs from one level to another as one ascends from sea level through the Plateau to the free air above, a specific case of the passage of a cyclone across this region has been selected and the corresponding pressure maps drawn for levels 1, 2, and 3 kilometers above sea level.

The cyclone.—The storm in question was that which crossed the United States during the period February 10–16, 1919. Upon the sea-level map, it appeared to enter the United States in the vicinity of Tatoosh Island, Wash., and proceed in a zigzag course across the Plateau in a southeasterly direction, constantly increasing in intensity, until, on the morning of February 13, it was centered at Kansas City, Mo., with the phenomenally low pressure of 978.7 mb. It had assumed an extraordinarily circular form and its diameter much exceeded the latitudinal extent of the United States. High winds prevailed in the Great Plains; dust storms and haze occurred far to the east. The progress of this storm from the Great Plains eastward has already been discussed.[2]

It is now proposed to pursue this storm across the mountainous Plateau. A similar attempt has recently been made by T. Kobayasi[3] in following a cyclone across the low mountains which parallel the east coast of the Korean Peninsula. But his mountain range does not attain the great heights of the Sierras or the Rockies, nor does he have a rugged plateau of vast extent. The presence of water areas within several hundred kilometers east and west of the peninsula would also undoubtedly produce effects markedly different from those of the American Plateau.

Upon the sea-level map, the successive 12-hour positions of lowest pressure were as follows:

February 10, 8 p. m., Tatoosh Island, Wash.
February 11, 8 a. m., Winnemucca, Nev.
February 11, 8 p. m., Yellowstone Park, Wyo.
February 12, 8 a. m., Denver and Pueblo, Colo.
February 12, 8 p. m., Amarillo, Tex.
February 13, 8 a. m., Kansas City, Mo.

From its first appearance until after it passed out of Colorado there was an obvious connection with low pressure farther to the north, beyond the Canadian border. At Winnemucca appeared the first closed isobars, but the number of them increased until, as described above, the circular formation of vast extent overlay the Great Plains and the Mississippi Valley. The evident connection with low pressure outside the field of the maps is significant.

MAPS FOR THE UPPER LEVELS.

Elevations in the Plateau.—While maps have been drawn for three upper levels, they can not, with the partial exception of that for 3 kilometers above sea level, be regarded as free-air pressure maps. There is, to be sure, along the Pacific coast a long strip of land very much closer to sea level than to any of the upper levels. But the Sierras and the Plateau rise abruptly to the east, with the result that most of the stations lie above the 1-kilometer level, and several lie above 2 kilometers. While there are no stations at present operating as high as 3 kilometers, it must not be forgotten that this level is penetrated by mountains at numerous places. In general, the 3-kilometer map represents conditions at the approximate level of the highest points in the Plateau, while the 1 and 2 kilometer levels lie, over considerable areas, below the surface.[4] These maps may be regarded, therefore, as attempts to show what the barometric distribution would have been had the earth been sliced off smoothly at those levels. The following table of stations shows their altitudes and the vertical distances from their barometers to the respective levels. The negative sign indicates that the reduction level lies *below* the station.

[1] Bigelow, Frank H.: Report on the barometry of the United States, Canada, and the West Indies. *Report of the Chief of the Weather Bureau, 1900–1901*, Vol. II, p. 774.

[2] Weisinger, C. LeRoy: The great cyclone of mid-February, 1919. MO. WEATHER REV., October, 1920, 48:582–586.

[3] Kobayasi, T.: On a cyclone which crossed the Korean Peninsula and the variation of its polar front. *Quar. Jour. Royal Met'l. Soc.*, April, 1922, pp. 169–184. Abstract in this REVIEW, p. 356.

[4] While it is not practicable to reproduce a hypsometric map of this region, the interested reader may find a sketch map in the May, 1920, REVIEW, p. 253, which will give an approximate idea of the areas above the several levels.

TABLE 1.—*Elevations of stations in western United States, and the length of reduction columns to the various levels.*

Station	Elevation.		Z_1 meters.	Z_2 meters.	Z_3 meters.
	Feet.	Meters.			
Tatoosh Island, Wash.	86	26	974	1,974	2,974
Spokane, Wash.	1,929	588	412	1,412	2,412
Seattle, Wash.	125	38	962	1,962	2,962
North Head, Wash.	211	64	936	1,936	2,936
Portland, Oreg.	153	47	953	1,953	2,953
Roseburg, Oreg.	510	155	845	1,845	2,845
Eureka, Calif.	62	19	981	1,981	2,981
Red Bluff, Calif.	332	101	899	1,899	2,899
Sacramento, Calif.	69	21	979	1,979	2,979
San Francisco, Calif.	155	47	953	1,953	2,953
Fresno, Calif.	327	101	899	1,899	2,899
Los Angeles, Calif.	338	103	897	1,897	2,897
San Diego, Calif.	87	26	974	1,974	2,974
Phoenix, Ariz.	1,108	338	662	1,662	2,662
Flagstaff, Ariz.	6,908	2,106	−1,106	−106	894
Tonopah, Nev.	6,090	1,856	−856	144	1,144
Winnemucca, Nev.	4,344	1,324	−324	676	1,676
Boise, Idaho	2,739	835	165	1,165	2,165
Baker City, Oreg.	3,471	1,058	−58	942	1,942
Kalispell, Mont.	2,973	906	94	1,094	2,094
Helena, Mont.	4,110	1,253	−253	747	1,747
Havre, Mont.	2,505	764	236	1,236	2,236
Miles City, Mont.	2,371	723	277	1,277	2,277
Yellowstone Park, Wyo.	6,200	1,890	−890	110	1,110
Sheridan, Wyo.	3,790	1,155	−155	845	1,845
Lander, Wyo.	5,372	1,637	−637	363	1,363
Pocatello, Idaho	4,477	1,365	−365	635	1,635
Salt Lake City, Utah	4,360	1,329	−329	671	1,671
Modena, Utah	5,479	1,670	−670	330	1,330
Grand Junction, Colo.	4,702	1,404	−404	596	1,596
Santa Fe, N. Mex.	7,013	2,138	−1,138	−138	862
Roswell, N. Mex.	3,596	1,087	−87	913	1,913
El Paso, Tex.	3,762	1,147	−147	853	1,853
Abilene, Tex.	1,738	530	470	1,470	2,470
Amarillo, Tex.	3,676	1,120	−120	880	1,880
Oklahoma City, Okla.	1,214	370	630	1,630	2,630
Dodge City, Kans.	2,509	765	235	1,235	2,235
Pueblo, Colo.	4,685	1,428	−428	572	1,572
Denver, Colo.	5,292	1,613	−613	387	1,387
North Platte, Nebr.	2,821	860	140	1,140	2,140
Cheyenne, Wyo.	6,088	1,855	−855	145	1,145
Rapid City, S. Dak.	3,259	993	7	1,007	2,007

Temperature gradients in the Plateau.—There is very little information available concerning temperatures above the surface in the western region, and this greatly complicates any attempt to reduce pressure. Unfortunately, there are no kite stations west of the 100th meridian. Such sounding-balloon ascents as were made off the coast of southern California a few years ago were made in the summertime, and conclusions which one might draw concerning gradients within these lowest 3 kilometers would not be applicable to February conditions. For some years records were kept on the summit of Pikes Peak, Colo. (4,301 meters) and these were subjected by Prof. A. J. Henry[5] to careful comparison with synchronous records at Colorado Springs, Colo. (1,858 meters); similar studies were made of data obtained at Corona, Colo. (3,554 meters), Leadville, Colo. (3,125 meters), and Denver, Colo. (1,613 meters). Valuable as these data are, it must be true, from what we know of kite data, that vertical gradients of temperature based upon measurements at two points separated by considerable vertical distance, both of which are surface stations, can not properly account for the sinuosities of the intervening lapse rate. Nevertheless, these mountain gradients afford the only thread of direct observation we have.

There is the line of aerological stations, consisting of Ellendale, N. Dak., Drexel, Nebr., Broken Arrow, Okla., and Groesbeck, Tex., from which considerable information is to be obtained regarding vertical gradients, but these stations are at a much lower level, and their results must be applied to mountain stations with discrimination.

The values given by Professor Henry, expressed in degrees centigrade, per 100 meters, for the gradient at Colorado Springs, are as follows:

[105th Meridian time.	
5 a. m.	0.44
6 a. m.	0.45
5 p. m.	0.70
6 p. m.	0.65

The 5 o'clock values are applicable to the observations taken in 120th meridian time.

For the kite stations, when the diurnal variation is not considered, the values are smaller than those given above, showing a tendency toward strong inversions in February at Ellendale, lesser inversions at Drexel, and small positive lapse rates at the two southern stations.[6] The kite records have the advantage of being integrated over small altitude divisions, whereas the mountain data are based on two points only.

Therefore, in cases where the air columns were quite long, and the latitude southerly, it was believed that, for morning observations, a gradient of 0.5° C. per 100 meters might reasonably be employed; that in middle latitudes 0.3° C. or 0.4° C. per 100 meters; and that in the north of the Plateau 0.2° C. per 100 meters. For short air columns a small positive or possibly a small negative lapse rate might account closely enough for the vertical temperature distribution. In the evening the lapse rate employed was, in all cases, higher.

Temperature gradients on the Pacific coast.—On the Pacific coast (which offers a different problem from that of the Plateau) at the time of this cyclone the station on Mount Tamalpais, near San Francisco, was maintained. Its altitude was only 724 meters above sea level and it could serve only in the most general way as an index to the mean temperature over San Francisco up to 1 kilometer above the sea. The vertical gradient between San Francisco and Mount Tamalpais at the time of the observations in question was about 0.7° C. per 100 meters, there being little difference between morning and evening observations. This indicated that along the Pacific coast a larger lapse rate should be used than that employed for interior stations.

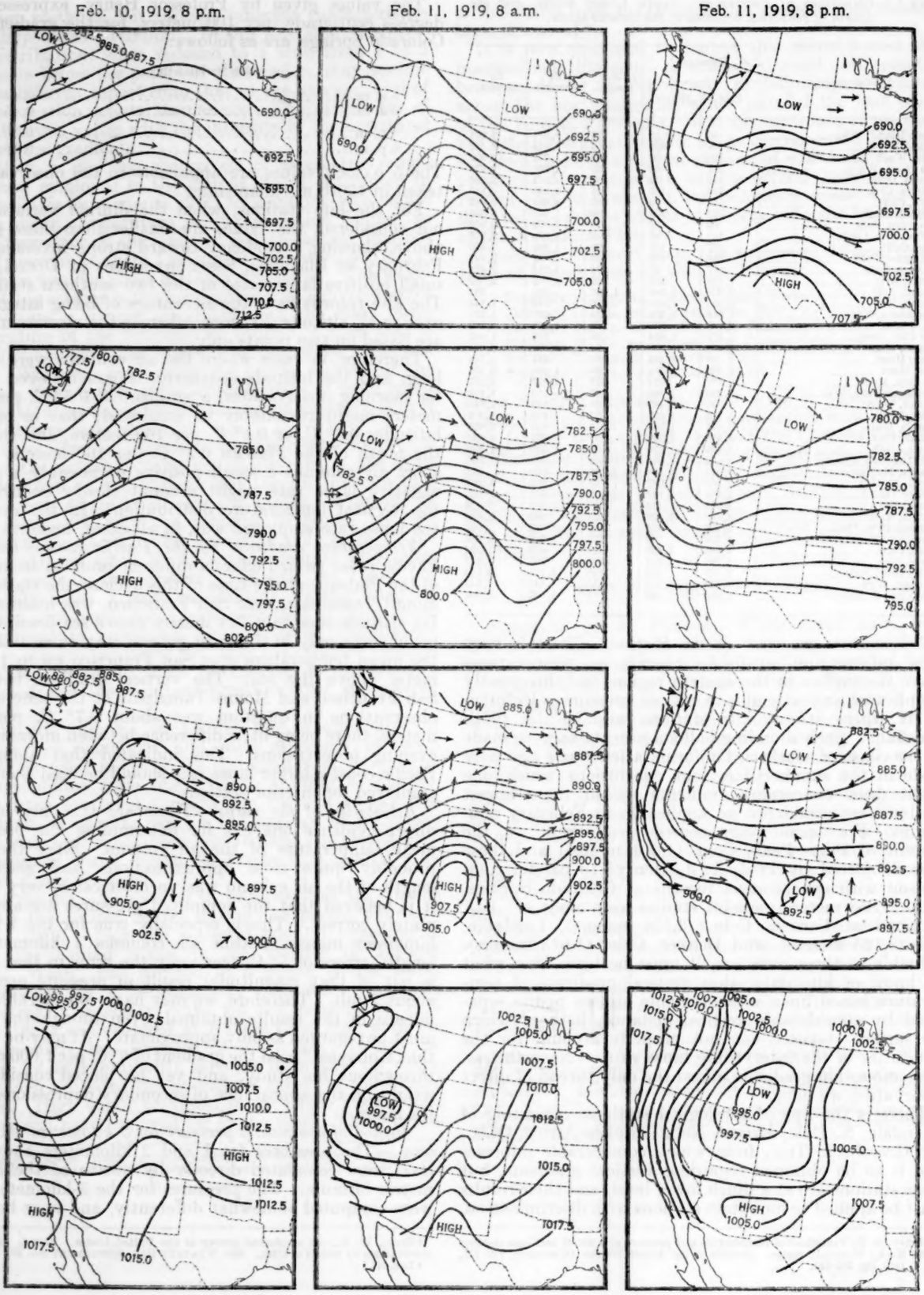
Reliability of the maps.—These are the only bits of direct evidence one has for determining the probable mean temperature of the air column. Since they are probably quite close approximations, and since the length of the air column was, in most cases, very short, it is believed that the computed pressures are approximately correct. This is especially true for the 1 and 2 kilometer maps. Within air columns 1 kilometer in length, errors of 5° C. (certainly the error in this study is not of that magnitude) result in pressure errors of about 2 mb. Therefore, we may have considerable confidence in the results obtained, even though the maps must be regarded as only approximate. It may be added that Kobayasi[7] used the gradient of 6° C. per 1,000 meters throughout his study, and yet he placed considerable weight on the appearance of secondary depressions upon his maps.

Method of computing pressure for 3 kilometers above sea level.—The pressures for 1 and 2 kilometers above sea level were calculated directly by means of the hypsometric formula. The pressures for the 3-kilometer map were computed somewhat differently, and may be, as a

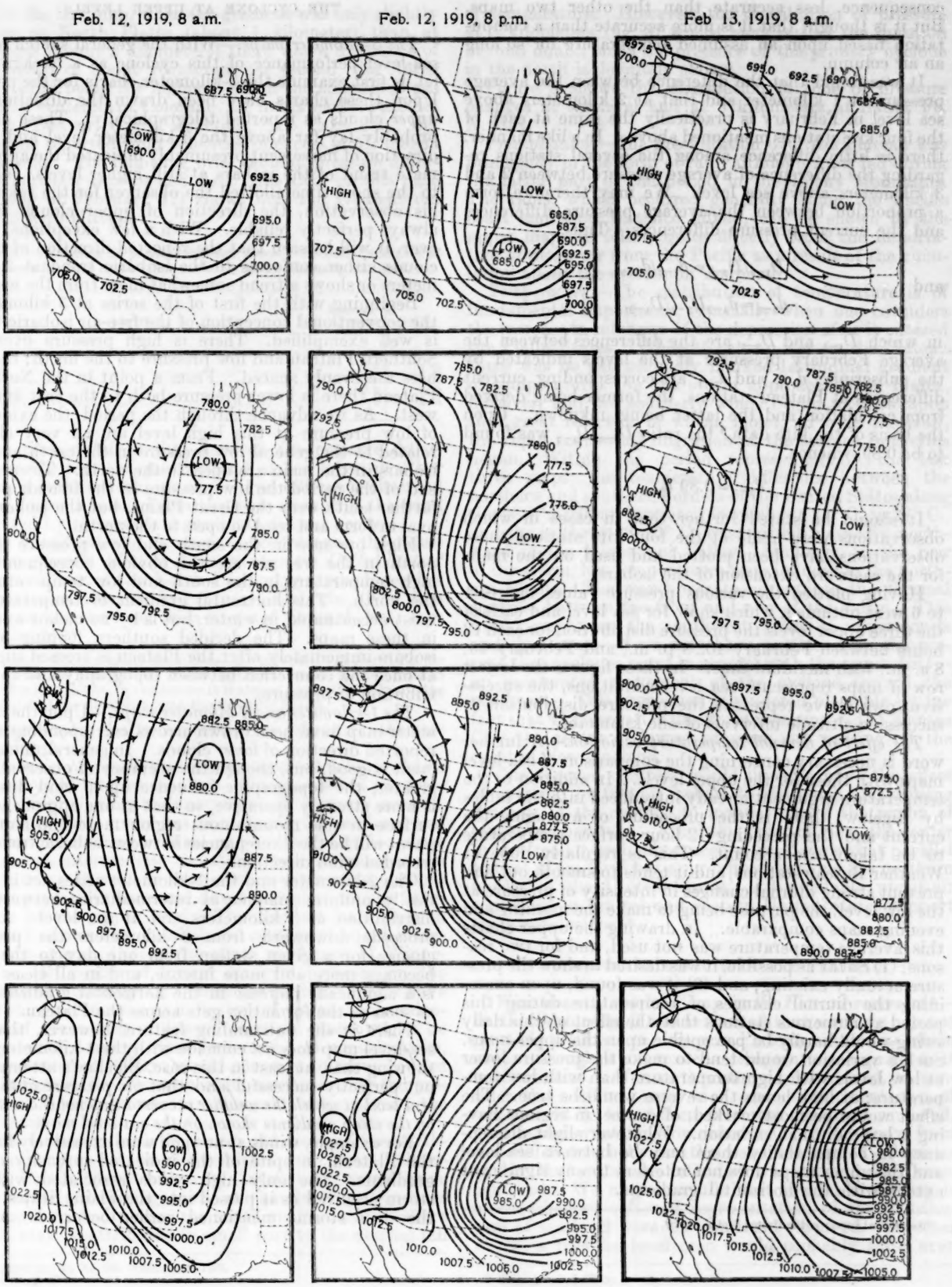
[5] Henry, A. J.: Variations of temperature and pressure at summit and base stations in the Rocky Mountain region. *Bulletin of the Mount Weather Observatory*, Vol. III, part 4, 1910, pp. 201–225.

[6] Gregg, W. R.: An aerological survey of the United States. Part I. Results of observations by means of kites. MO. WEATHER REV. SUPPLEMENT No. 20.

[7] Loc. cit.



FIGS. 1–3.—Barometric pressures and winds at various levels in the Plateau region, February 10, 1919, 8 p. m., and February 11, 1919, 8 a. m. and 8 p. m., 75th meridian time
From bottom to top the levels represented are, successively, sea-level, 1, 2, and 3 kilometers.



FIGS. 4-6.—Barometric pressure and winds at various levels in the Plateau region, February 12, 1919, 8 a. m. and 8 p. m., and February 13, 1919, 8 a. m., 75th meridian time. From bottom to top the levels represented are, successively, sea-level, 1, 2, and 3 kilometers.

consequence, less accurate than the other two maps. But it is thought that it is more accurate than a computation based upon an assumed temperature for so long an air column.

It was found that the difference between the average pressure at 1 kilometer and that at 2 kilometers above sea level in February is practically the same at each of the four kite stations mentioned above. In a like manner, there is little difference among the several stations regarding the difference of average pressure between 2 and 3 kilometers above sea level. We may therefore form a proportion between the average pressure differences and the current pressure differences. Thus,

$$D_{1-2}/D_{2-3}=d_{1-2}/d_{2-3}$$

and

$$d_{2-3}=d_{1-2}D_{2-3}/D_{1-2},$$

in which D_{1-2} and D_{2-3} are the differences between the average February pressures at the levels indicated by the subscripts; d_{1-2} and d_{2-3} are corresponding current differences at Plateau stations, the former being derived from calculation and the latter being unknown. Upon the basis of the kite data,[8] the ratio D_{2-3}/D_{1-2} was found to be 0.89, whence,

$$d_{2-3}=0.89\ d_{1-2}$$

It should be stated further that in cases in which observations were made at the four kite stations those observations have been plotted and used on the maps for the eastward extension of the isobars.

Having plotted the various pressure values figures 1 to 6 were obtained, which show for sea level and each of the three upper levels the pressure distribution for each 12 hours between February 10, 8 p. m., and February 13, 8 a. m., 75th meridian time. In these figures the lowest row of maps represents sea level conditions, the successive rows above represent the pressure distribution at successive altitude intervals of one kilometer.

The effect of diurnal temperature variation.—A further word is necessary concerning the comparison of sea-level maps with those for the upper levels. In addition to the temperature argument already introduced into the tables by Bigelow, there is the procedure of averaging the current and the preceding 12-hour surface temperature to be taken into account. This is regularly done at Weather Bureau stations, and it tends to smooth out and prevent strong diurnal changes in intensity of pressure at the low level, the purpose being to make the morning and evening maps comparable. In drawing the upper charts this average temperature was not used, and for two reasons: (1) So far as possible, it was desired to show the pressure actually existing; and (2) it was found, upon examining the diurnal changes of temperature during this period at numerous stations that the effect of this daily swing would hardly be perceptible upon the upper maps. Such a variation would tend to make the pressure lower at low levels with high temperature than with low temperature; at high levels the reverse would be true. The effect would be most marked, of course, in regions having a large diurnal variation. Whatever slight discrepancy in comparability there may be between sea level and the upper maps does not interfere to any significant extent with the horizontal gradients.

[8] Aerological Survey of the United States, *loc. cit.*

THE CYCLONE AT UPPER LEVELS.

The 3-kilometer maps.—With the general sketch of the sea-level performance of this cyclone as a background, let us first examine the 3-kilometer charts for the period. Upon these charts have been drawn the directions of *upper* clouds as reported telegraphically. These clouds probably lay far above the 3-kilometer level and their direction of movement presumably indicated the approximate trend of the isobars at still higher levels. Owing to the short time allotted the observer for the taking of his observation, the direction of upper clouds is not always perfectly reliable. With a few exceptions, however, it will be seen that the reported direction of upper clouds either conforms to the isobaric trend at 3 kilometers or shows a trend somewhat more from the west.

Beginning with the first of the series at 3 kilometers, the conventional conception of the free-air isobaric trend is well exemplified. There is high pressure over the Southern Plateau and low pressure to the north; the isobars are evenly spaced. From a point in the Northern Plateau there is lower pressure both to the east and the west. As we advance through the period, the evidences of low pressure at this high level are all very closely related to the general low pressure in the north and the isobars in the main are open to the north. Toward the end of the period the low pressure in the free air pushes farther south over the Great Plains, but the isobars are oval in form and tend to open to the north.

High pressure in the south and low pressure in the north in the free air are the obvious consequences of high temperature in the south and low temperature in the north. This horizontal gradient of temperature is most accentuated in winter, but is by no means extreme in these maps. The decided southern looping of the isobars immediately after the Plateau is crossed suggests at once the connection between topography and the distribution of pressure.

The 1-kilometer and 2-kilometer maps.—Upon the 2-kilometer map have been drawn arrows corresponding to the reported direction of *lower* clouds. In general, the agreement is good, but, though the accuracy of observation is greater, the topographic influence upon wind direction is more strongly operative, so that as one approaches the surface in this mountainous region more and more frequent will be the discrepancies between isobaric trend and recorded wind direction.

The 2-kilometer and the 1-kilometer series act in practically uniform manner as intermediaries between the distribution at 3 kilometers and at sea level. As one proceeds downward from 3 kilometers the pressure change for a given station from one day to the next becomes more and more intense, and in all cases there is a significant increase in the horizontal gradients just as soon as the formation gets across the Plateau.

There is the outstanding feature, however, that the sea-level map *does not* coincide with the 1-kilometer map, showing that, at least in this case, Bigelow's attempt was not perfectly successful and that *the pressure at the general level at which the weather occurred was not characterized by the steep gradients shown on the sea-level map.*

For example, winds at no time were excessively high on the Plateau, in spite of the indicated intensity of the gradients. The only high winds associated with the storm occurred as it passed into the Plains States, when the dust storms mentioned earlier occurred. At the

time of the last map, when the gradient was only slightly steeper at North Platte (about 1 kilometer) than at Cheyenne (about 2 kilometers) there was a difference of wind speed of about 10 meters per second, the North Platte wind being the higher. When the storm was apparently centered in Colorado, 24 hours earlier, neither Pueblo, Denver, Grand Junction, Salt Lake City, nor Cheyenne reported wind velocities in excess of 5.3 meters per second. The following brief table of pressure differences between Denver and Salt Lake City on this date (morning of February 12) shows how the gradient decreased with altitude:

TABLE 2.—*Difference in pressure between Denver and Salt Lake City at various levels, 8 a. m. (75th meridian time), February 12, 1919.*

Level.	Pressure difference *mb.*	db/dB.
Sea level	11.5	1.00
1 kilometer	10.0	0.87
2 kilometers	7.0	0.61
3 kilometers	7.0	0.61

The ratio db/dB is that between the pressure difference at the level in question and at sea level; in other words, it is the percentage of sea-level difference observed at the upper levels. From this it is clear why the wind indicated by the sea-level gradients did not occur.

The classification of the storm.—According to the classification given in *Weather Forecasting in the United States*,[9] this storm was of the North Pacific type, which reaches its maximum intensity in February, as a rule. The path taken on the sea-level map was not unusual, but, says the manual:[10]

> By reason of topographic conditions, the movement of North Pacific LOWS across the Plateau and Rocky Mountain region is often masked and difficult to follow; in some cases it is almost impossible to locate the true center of the disturbance on the synoptic charts.

The synoptic charts mentioned are, of course, the sea-level charts.

Allobaric charts and their significance.—Allobaric charts are always of interest, because of their value to the forecaster in predicting the movement of pressure centers. A series of these maps has been drawn for sea level and also for 3 kilometers. These two levels will suffice, since changes at intermediate elevations were intermediate in magnitude. It will be seen that the pressure changes are, in general, in the same direction but of smaller magnitude at the upper level. The first sea-level map in Figure 7 shows two katallobaric centers of equal intensity, the one southeast, the other northeast, of Winnemucca, the center of lowest sea-level pressure on the morning of February 11. Since the allobaric charts have their chief significance as indicators of the probable movement of the center of lowest pressure, there might be some doubt, leaving other factors out of consideration, as to whether the storm would continue to move toward the southeast (the direction of its motion during the previous 12 hours) or whether it would move toward the northeast.

As a matter of fact, the center did move to the northeast and appeared, on the sea-level map, near Yellowstone Park. The 3-kilometer katallobars would have been equally deceiving, since at that level the pressure fell most markedly over the southern Plateau, an effect which may be attributed in small part to the diurnal fall of temperature. However, the distribution of pressure at 3 kilometers (fig. 3) would have settled the question beyond doubt, since the presence of the primary cyclone in the north is definitely shown.

Figure 8 shows the distribution in time of pressure changes at sea-level and at 3 kilometers at Santa Fe, N. Mex.

Precipitation.—The precipitation over the Plateau was principally in the form of rain, although snow fell during the latter part of the period in the Rocky Mountains. The rains, which occurred generally along the Pacific coast and some distance inland, can be shown by the upper maps to follow quite directly from the importation of moist air from the Pacific as a result of the circulation about the cyclone in the north.

Temperature.—The distribution of temperature is of fundamental importance, especially when one considers the increase in intensity of the depression after it entered the Plains States. While the storm was on the Plateau there was no exceptionally marked latitudinal gradient of temperature. As the storm approached the Plains, however, and the southerly winds began to draw upon that great reservoir of warm, moist, air over the Gulf, the rapid northward migration of the surface isotherms began. Within the period represented by the last three maps, the temperature difference between the northern and southern borders of the United States along the 95th meridian increased from about 11° C. to 28° C., and the isotherm of 10° C. was shifted markedly northward in the Mississippi Valley. Similarly, in the rear of the storm, low temperatures were induced in the northern Plains. The result was to accentuate the thermal contrast between the front and rear of the storm. This would emphasize the southwest winds at upper levels and thus cause—if we may have confidence in the precept that cyclones move in general with the upper drift—an accelerated movement of the cyclone toward the northeast. This suggestion is rendered plausible by the fact that 48 hours after the storm was centered at Kansas City the center of lowest pressure was passing off the coast of New England.

This thermal contrast would likewise have the effect of opening the free-air isobars to the north and causing the axis of the cyclone to incline toward the region of lowest temperature. From this point of view, the center in the free air probably traced a track somewhat parallel to that at sea level but approximately along the northern border of the United States. All available upper-air soundings in central and eastern United States support these conclusions.[11]

HYPSOMETRIC EFFECTS IN THE PLATEAU.

What does the sea-level map in the Plateau represent?—In the beginning, it was remarked that since we can not precisely evaluate the error in Plateau reductions which arises through an erroneous temperature argument, it is convenient, so far as this study is concerned, to consider the sea-level map as a correct representation of what might be found there were the continent removed. This is not what Bigelow intended, but we know from the difference between the sea-level and 1-kilometer charts that what he intended was not, in this case, achieved. We may conclude that the sea-level map is a smoothed or softened representation of the distribution at sea level were the continent removed. In other words, a true sea-level map would probably show even

[9] Weather Bureau No. 583, Washington, 1916.
[10] *Op. cit.*, p. 120.
[11] Meisinger, C. LeRoy: *loc. cit.*

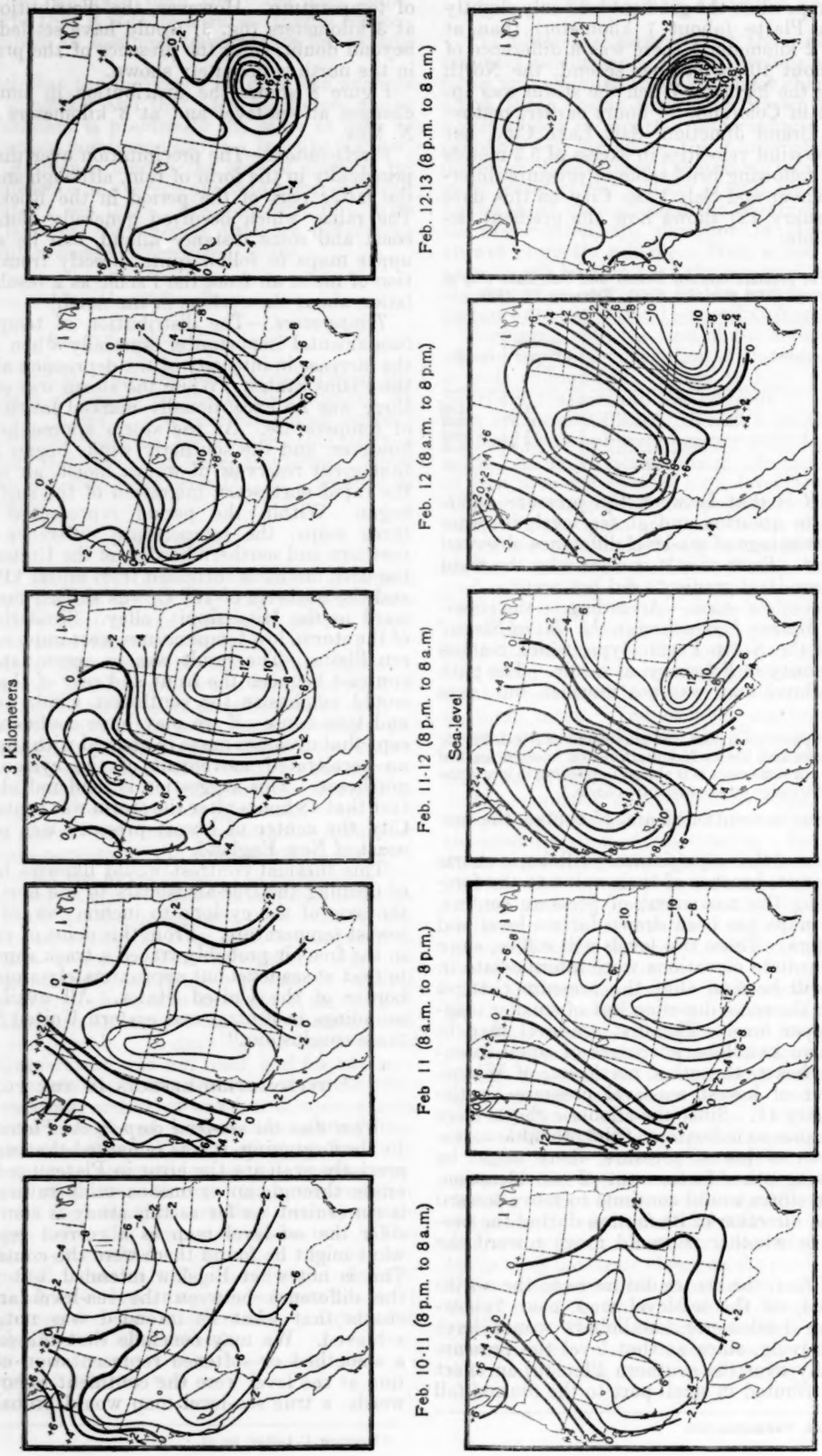


FIG. 7.—Pressure changes for 12-hour periods at 3 kilometers above sea level and at sea level.

steeper horizontal gradients than the present one, reduction errors neglected.

The hypsometric formula.—To make this thought clearer, let us recall certain consequences of the hypsometric relation which must make their effect apparent at different levels. In exponential form, this relation is

$$B = b\, e^{\frac{Z}{K(1+\alpha\theta)}}$$

in which B is the pressure at a lower level, b the pressure at an upper level, K the barometric constant, 7991, Z the length of the reduction column, α the coefficient of gas expansion and θ the virtual mean temperature of the air column. If this equation is differentiated, we have,

$$dB = db\, e^{\frac{Z}{K(1+\alpha\theta)}}.$$

From this it is apparent that, for a given gradient of pressure at an upper level, the gradient at a lower level will be somewhat greater, depending upon the distance between the two levels and the temperature. Specifically, if db is 10 mb., Z, 3,000 meters, and θ, 0° C., we find that dB is 14.5 mb.

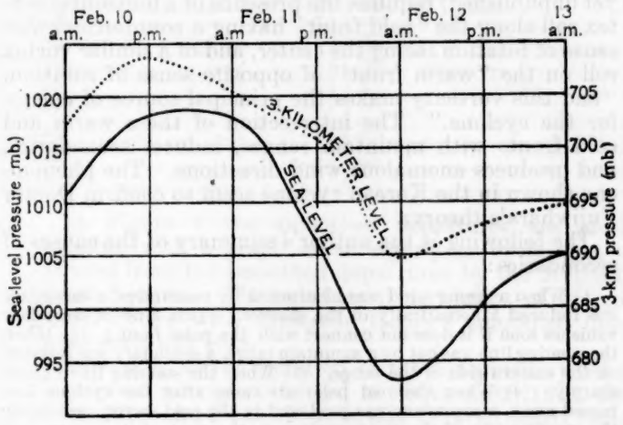


FIG. 8.—Pressure changes at sea level and 3 kilometers above sea level at Santa Fe, N. Mex.

This assumes no difference in the mean temperature of the air column. But if there is a difference of 5° C.,—and since higher temperature is usually associated with falling pressure—we assume the higher temperature at the station of lower pressure, and find that dB is increased to 22.1 mb., over twice the gradient at the upper level. Exner has shown [12] how pressure differences at the surface are a complex of pressure and temperature effects as shown by sounding-balloon data and by partial differentials of free-air pressure and mean temperature of the air column.

The essential point is that gradients of considerable magnitude may appear at sea level corresponding to lesser gradients at the Plateau level. But there is no atmospheric circulation to correspond to the sea-level gradients because there is no atmosphere at that level.

Since we may consider the barometric depression as superposed upon the northward-sloping, temperature-induced, isobaric surfaces, it is apparent that the center of lowest pressure will be shifted northward at each succeeding upper level. The maps here presented confirm this reasoning, and we find upon the sea-level map a system of stronger gradients with closed isobars lying south of the center of lowest pressure at upper levels.

[12] Exner, F. M.: *Dynamische Meteorologie.* Berlin, 1917, pp. 233-238. Cf. also discussion in *Ibid.*: *Über Luftdruckschwankungen in der Höhe und am Erdboden*, Meteorologische Zeitschrift, September, 1913, pp. 429-436; also November, 1913, pp. 563-564.

PLAINS AND PLATEAU EFFECTS COMPARED.

What happens when the storm passes off the Plateau into the Great Plains? We have already noted the general increase in activity and intensity in the latter part of the period and there are several effects to be taken into consideration in this regard. Supposing, first of all, that there were no increase in the intensity of the storm; what differences might arise between Plateau weather and Plains weather?

(1) As the storm moves eastward, the more active gradients at lower levels become real. There results a natural increase in the speed of the winds, and the circulation at the surface corresponds more closely to that indicated by the sea-level map.

(2) Surface friction over the level plains is much smaller than that over the rugged mountains, hence higher wind velocities are to be expected. There is the effect of greater density at lower levels than at the Plateau level which would tend to counteract this increase to a certain extent.

(3) With warm, moist air to draw upon in its southeastern quadrant, the thermal contrast between front and rear of the cyclone would be increased. This would cause a shift of the center of low pressure in the free air to the region of lowest temperature, and induce a general lowering in elevation of the southwesterly air stream aloft. Warm, moist air would thus overrun the sea-level center of lowest pressure.

Increase in intensity.—Not only did the storm show all the effects mentioned above, but it showed a marked increase in intensity which reached a climax at Kansas City and then gradually decreased with further eastward movement. This increase in intensity may be the result of the following effects:

(1) It was suggested that reduced sea-level gradients in the Plateau were not as strong as they might have been had Bigelow not attempted to make sea level show surface conditions. In the Plains States the stations are close enough to sea level that no great errors result in reduction thereto. Hence a given gradient in the free air should correspond to a steeper gradient in the Plains States than in the Plateau. This may account in part for the apparent increase in intensity after leaving the Plateau.

(2) Considered statically, the increase in temperature above the sea-level center of the storm combined with the lesser density of the moist air and reinforced, perhaps, by the retarded lapse rate of temperature (for precipitation was general by the morning of the 13th over the Southern States and central valleys) would operate to lower the sea-level pressure. The warm and cold fronts were, at this time, well developed, and this implies an upward component in the motion of the southerly air, both because of the forced convection of warm air overriding the cold air north of the warm front, and also because of convergence within the southerly stream itself.

(3) Whatever the nature of the dynamic effects which may have operated to increase the storm's intensity as it proceeded from the Plateau to the Plains, it appears that the interaction of the southwestward-moving cold-

air stream to the north and the northeastward-moving warm stream to the south of the center was an important factor. J. Bjerknes and H. Solberg [13] have recently emphasized this point. On page 15 of the work cited they say:

> At the limit between a polar current and a tropical current to the east of it the two currents are deflected from each other, so that an air deficit results above the region of their mutual limit. The low-pressure system, formed in that way, corresponds to a cyclone family.

And, again, on the following page:

> As soon as an easterly polar current and a westerly tropical current become too strong a cyclone forms between them and makes the currents encroach upon each other, diminishing their differences of velocity.

CONCLUSION.

It seems reasonable to conclude, therefore, that maps representative of conditions at and above the average level of stations in the Plateau would be of assistance to the forecaster in distinguishing between those barometric gradients on the sea-level map which are real and those which are either erroneous or follow as a consequence of the hypsometric relation. Further, the change in the character of the weather after the storm passed from the Plateau to the Great Plains is plainly due to (1) the effect of stronger gradients near sea level becoming real through having an actual atmosphere in which to exist; (2) the sea-level gradients becoming stronger upon leaving the mountain district because of moderating effects in the reduction method; and (3) actual increase in intensity of the storm.

A CYCLONE WHICH CROSSED THE KOREAN PENINSULA

By T. KOBAYASI.

[Abstracted from *Quar. Jour. Roy. Met'l Soc.*, April, 1922, pp. 169-184.]

With the twofold object of studying the phenomena induced by the passage of a cyclone directly across a mountain range, and of noting the behavior of the polar front in the Far East, the author makes a series of maps representing pressure distribution at sea level, at intervals of four hours between 10 a. m. March 24, and 2 a. m. March 26, 1918. Upon the assumption of a lapse rate of 6° C. per 1,000 meters for all stations, pressure maps at 3 kilometers above sea level are drawn to correspond to 6 of the sea-level maps.

At the time when the cyclone was 500 kilometers west of the Korean Peninsula, which "projects from the southeast coast of the Asiatic Continent in the direction of south-southeast, the width being from 200 to 300 kilometers, the length about 600 kilometers," and which contains a mountain range from 500 to 1,000 meters in height along its eastern coast, a secondary cyclone was induced on the eastern side of the peninsula, but it disappeared within four hours. But by the time the cyclone had advanced 100 kilometers, a second secondary, with a well-developed polar front, had appeared. The formation of these secondaries, according to the author, is due to the strong wind of the primary storm being obstructed by the mountains.[1]

The free-air maps show that these secondaries did not extend much above 3 kilometers and their axes are so inclined as to "wind themselves around the main cyclone."

A third secondary, associated with a sharp bend in the steering line, formed to the northeast of the main center. The free-air maps show the centers of the primary and the last two secondaries drawing gradually together, as if they were joined together at some higher level. The eastern secondary continually increased in intensity, while the primary diminished; the northern secondary finally joined with the eastern center, and finally the western center disappeared entirely. Thus, the cyclone crossed the peninsula.

Considering the cyclone from the Bjerknesian point of view, the behavior of the storm was quite normal, except as it was influenced by topography. Dr. S. Fujiwhara's new theory of the mechanism of extratropical cyclones (as yet unpublished) requires the presence of a horizontal vortex roll along the "cold front" having a counterclockwise sense of rotation facing the center, and of a similar vortex roll on the "warm front" of opposite sense of rotation, "and this vorticity makes the principal source of energy for the cyclone." The intersection of these warm and cold fronts with mountain ranges, induces secondaries, and produces anomalous wind directions. The phenomena shown in the Korean cyclone seem to confirm Doctor Fujiwhara's theory.

The following is the author's summary of the causes of secondaries:

> (1) When a strong wind was obstructed by mountains, a secondary was induced kinematically in the shadow. (This kind of secondary vanishes soon if it does not connect with the polar front.) (2) When the steering line was cut by a mountain range, a secondary was induced on the eastern side of the range. (3) When the steering line curved sharply. (4) When the real polar air came after the cyclone had passed away, a secondary was produced in the cold sector, prolonging the steering line of the main cyclone to the west of its center. (5) Along the squall line when the fault of the isobars became very large.

The paper is concluded by miscellaneous remarks concerning the storm: the inclination of the axis of the cyclone is less over the sea than over the land. In the latter case, the lower part of the cyclone is nearer the sea than the upper portion.[2] This cyclone acts in accordance with Prof. T. Terada's conclusions from a statistical study of cyclones in the Far East, namely, that cyclones tend to pass over land in summer and tend to avoid land in winter.—*C. L. M.*

[13] Bjerknes, J., and Solberg, H.: Life cycle of cyclones and the polar front theory of atmospheric circulation. *Geofysiske Publikationer*, Vol. III, No. 1. Christiania, 1922.

[1] Cf. Brooks, C. F.: On the origin of some secondary cyclones on the Middle Atlantic Coast. MO. WEATHER REV., January, 1921, 49: 12-13.

[2] Preliminary studies of cyclones in the eastern United States show this same tendency, which is explained by strong contrasts of temperature between the southeast and northwest quadrants of the storm. In summer, the axis is more nearly vertical as was found to be the case over the sea, in Doctor Kobayasi's cyclone, probably due to the less-marked horizontal temperature contrast in the lowest 3 kilometers.—*C. L. M.*

AN EIGHT-YEAR CYCLE IN RAINFALL.

By HENRY LUDWELL MOORE.

[Columbia University, August 4, 1922.]

The table on *Rainfall departures, United States (as a unit)* that appeared in an article by Prof. A. J. Henry in the March number of this REVIEW [1] supplies invaluable data for the theory of rainfall cycles. In Table 1 Professor Henry's figures relating to the smoothed rainfall departures are tabulated. The method of smoothing the data that was followed by Professor Henry is given by "the formula $b = \frac{1}{4}(a + 2b + c)$ where b is the middle year in any consecutive series of three years."

TABLE 1.—*Rainfall departures, United States (as a unit).*

Years.	Smoothed departures.	Years.	Smoothed departures.
1881	+0.4	1901	−2.1
1882	+0.2	1902	−2.0
1883	±0.0	1903	−2.5
1884	+0.4	1904	−2.6
1885	−0.4	1905	−1.0
1886	−2.7	1906	−0.4
1887	−3.2	1907	−1.6
1888	−2.1	1908	−1.8
1889	−2.0	1909	−2.4
1890	−2.4	1910	−3.8
1891	−1.3	1911	−2.6
1892	−2.5	1912	−1.1
1893	−3.1	1913	−1.8
1894	−3.5	1914	−1.9
1895	−3.2	1915	−1.5
1896	−2.1	1916	−3.2
1897	−1.6	1917	−4.7
1898	−2.1	1918	−3.4
1899	−2.2	1919	−1.5
1900	−2.0	1920	−0.9

In Figure 1 the smoothed departures are plotted together with a graph of an eight-year cycle that was derived from the smoothed departures by the Method of Least Squares. The substantial agreement of the computed cycles with Professor Henry's smoothed departures *saute aux yeux*.

According to the equation of the computed cycles the theoretical maxima occurred at about 1882, 1890, 1898, 1906, 1914, and I was about to add 1922, so nearly certain does it seem that the present year will be characterized by an unusually large rainfall. In other places [2] I have shown that eight-year cycles with approximately these same dates for maxima occur in the rainfall of the Ohio Valley, the rainfall of Illinois, the May and June rainfall of the Dakotas, the barometric pressure in the United States, the winter barometric pressure in Central Europe,

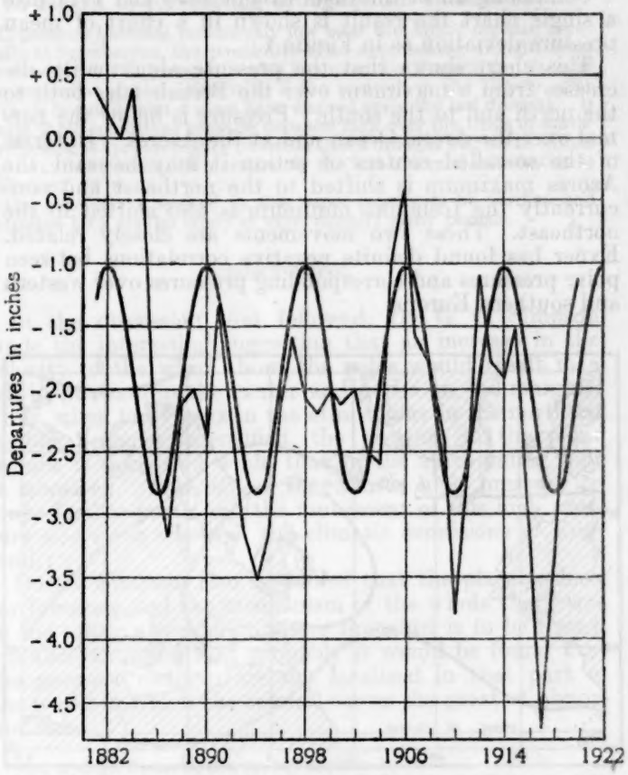


FIG. 1.—Smoothed departures of rainfall in the United States (as a unit). Equation to the eight-year cycle: $y = -1.95 + 0.90 \sin(45°t + 43°37')$, origin at 1881.

the yield of crops in the United States, the yield of crops in the United Kingdom, the yield of crops in France, and the index number of general wholesale prices throughout a century.

[1] MO. WEATHER REV., March, 1922, p. 130.
[2] Particularly "The Origin of the Eight-Yea] Generating Cycle." *Quarterly Journal of Economics*, November, 1921.

BROOKS AND GLASSPOOLE ON THE DROUGHT OF 1921.[1]

By A. J. HENRY.

The first section of this paper is devoted to a discussion of the 1921 and other dry periods in the British Isles. The second section takes up the causes of droughts and it is with this section that readers of the REVIEW will be particularly interested.

It is recognized that the establishment and maintenance of local anticyclonic conditions is closely associated with dry weather; the immediate concern, therefore, is to discover, if practicable, how the local abnormalities of pressure distribution are related to others in the general circulation in different parts of the world.

Charts were constructed showing the deviation of pressure from the normal over a considerable portion of the Northern Hemisphere for the 1921 and other severe droughts. The periods are as follows:

April to August, 1864.
May to July, 1868.
October to January, 1880.
February to October, 1887.
March to June, 1893.
February to June 1895.
January to May, 1896.
July to October, 1911.
February to October, 1921.

The pressure distribution for the above periods fell clearly into two types which were designated the A and the B types. The A type, however, comprised but two droughts—February to June, 1895, and August to October, 1911. This type is characterized by high pressure to the north of the British Isles. The Icelandic minimum is shifted toward West Greenland and the Azores maximum is feebly developed. In this case

[1] C. E. P. Brooks and J. Glasspoole: The Drought of 1921, *Quart. Jour. XLVII*, p. 139–166.

the drought is said to be due to dry winds rather than to anticyclonic conditions. Depressions were few and either passed to the south across the Bay of Biscay or descended from the Arctic Ocean southward or southeastward across Scandinavia.

Type B, which includes the remainder of the examples, is characterized by a region of maximum positive pressure abnormality centered directly over the British Isles amounting to 4 mb. (0.12 inch) at the central portion.

Combining all of the cases except 1895 and 1911 into a single chart the result is shown in a chart of mean pressure deviation as in Figure 1.

This chart shows that the pressure abnormality decreases from a maximum over the British Isles both to the north and to the south. Pressure is below the normal over the Arctic Ocean and at the Azores. In terms of the so-called centers of action it may be said the Azores maximum is shifted to the northeast and concurrently the Icelandic minimum is also shifted to the northeast. These two movements are closely related. Exner has found definite negative correlations between polar pressures and corresponding pressures over western and southern Europe.

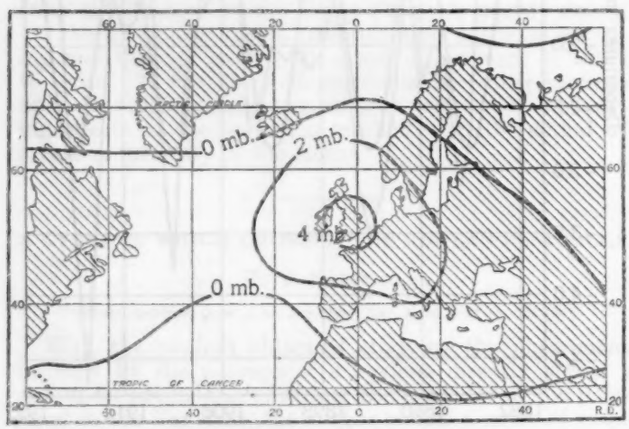


FIG. 1.—Chart of pressure deviation: mean of seven droughts.

It is evident, therefore, that high pressure in the Temperate Zone is closely associated with low pressure near the poles, at least in winter. In order to examine the question more closely, the authors next correlated the pressure at Valencia with corresponding pressures at Stykkisholm, Berlin, Ponta Delgada, and Vardo with the result that Vardo is definitely opposed to Valencia in all seasons except summer, when it apparently lies between the European and the Arctic régimes. In this season the Arctic center lies farther north, for, taking the 12 years which are unfortunately all that are available for Spitsbergen the authors get a correlation with Valencia of −0.78 in summer. Further, when they calculate from the above coefficients and the standard deviations the difference from normal corresponding to 4 mb. at Valencia they find good agreement with the results shown in Figure 1. This indicates that drought conditions are not isolated phenomena but are merely the extreme cases in one direction of the usual variations to which the pressure distribution, and therefore the atmospheric circulation, is liable.

The cause of drought in the British Isles must, therefore, be looked for in some variation in the strength of the atmospheric circulation. As between the polar regions and the Tropics the former is the better of the two as an indicator of a change in the temperature gradient and naturally a corresponding change in the strength of the circulation.

The authors show that low pressure in the polar regions is associated with droughts of Type B. Low pressure in those regions is associated with great storminess and high temperature. The dearth of meteorological stations in the Arctic makes it impossible to confirm this statement by the usual statistical methods; the belief is expressed, however, that warm weather in the Arctic Ocean is associated with, and perhaps causes, a more northerly position of the subtropical anticyclones and, consequently, high pressure over the British Isles.

The relation of droughts to the sunspot cycle, variation in the amount and position of Arctic ice, and the periodic movement of the Icelandic minimum are next discussed in separate paragraphs.

With reference to the sunspot relation it is pointed out that according to Fisher [2] a few years (1 to 4½) after sunspot maximum the Azores anticyclone tends to extend northward over Spain and the Bay of Biscay or even over the British Isles.

Droughts are accordingly most frequent at this stage of the cycle (4 years after spot maximum). The data of droughts are, however, so spread over the cycle that the result is not of great value.

A movement of the Icelandic minimum having a period of 8 months, and another having a period of 4.8 years, is distinguished. Accounts as to the interaction of the Icelandic minimum and the surface temperature of the North Atlantic are due to several investigators. W. Meinardus and J. Petersen are quoted specifically. According to them, when the Icelandic minimum lies to the westward of its normal position, say over West Greenland, the southwest winds between Iceland and northwest Europe will be unusually strong and steady. These warm winds will raise the temperature of the surface waters both by their own high temperature and by strengthening the Gulf Drift. This warm water after a time draws the Icelandic minimum eastward and also causes it to become more intense, which still further increases the temperature and velocity of the Gulf Drift. But it also increases the cold currents, especially the Labrador Current, and cools the Gulf Drift and, after the necessary time, this cools the northern seas and induces a fall of temperature over the Northeastern Atlantic, so that pressure rises again there and the Icelandic minimum retreats westward becoming less intense at the same time.

This hypothesis was tested by the Reseau Mondial charts of pressure deviation for the years 1910–1915 and was found to represent the facts shown there very accurately.

The short period movements of the Icelandic minimum from 1910 to 1915 are shown in the statement below:

MINIMUM TO WESTWARD.	MINIMUM TO EASTWARD.
August to October, 1910.	January to July, 1910.
January to May, 1911.	November to December, 1910.
July to November, 1911.	June, 1911.
April to May, 1912.	December, 1911, to March, 1912.
October to November, 1912.	June to September, 1912.
February, 1913.	December, 1912, to January, 1913.
June to September, 1913.	March to May, 1913.
July to November, 1914.	October, 1913, to June, 1914.
October, 1915.	December, 1914 to April, 1915.
	November to December, 1915.

[2] Das Wetter, 1916, p. 232.

Examination of the Reseau Mondial charts suggests that there is also a northeast-southwest oscillation of the Icelandic minimum ranging from Spitsbergen or northern Russia to Newfoundland, which takes place much more slowly. Since the greatest droughts occur when this minimum is not to the west over Greenland but unusually far north toward Spitzbergen, this longer oscillation is discussed at some length. There is strong reason the authors assert for supposing that this northeast-southwest oscillation of the Icelandic minimum is connected with the ice conditions in the Arctic waters, for droughts of Type B in the British Isles are followed by years with much ice near Iceland.

The sequence of events leading up to a drought in the British Isles with low pressure in the neighborhood of Spitzbergen is about as follows: In the Arctic Ocean the temperature is abnormally high and the weather is stormy. Consequently, the polar ice is broken up and much floe and field ice drifts into the East Greenland current. Owing to the prevalence of strong westerly winds this ice is spread out to the eastward of its normal limits and some of it collects around the shores of Iceland. Between Spitzbergen and Iceland the average velocity of the ice is about 7 miles a day, so that it would take some 200 days, or nearly 7 months, on the journey, and the ice broken up in summer would appear off Iceland early in the following year. The Arctic ice generally passes Cape Farewell in January or February. It follows the southerly current up the west coast of Greenland nearly as far as Disko Island, 70° north. Here it is driven westward by the easterly winds of spring, after which it again drifts southward along the western side of Baffin Bay and Davis Strait into the Labrador Current, which carries it past Newfoundland into the Gulf Drift.

As the floating ice melts it must cause an appreciable cooling and this cooling is propagated to the northeastward with the velocity of the current and it finally reaches the Northeastern Atlantic. The deficit in temperature of the Gulf Drift is followed by a cold season in the Arctic Ocean with high pressure and an absence of storminess. Hence there is little loose ice to be swept into the East Greenland current and the whole sequence begins again, but with the values reversed.

The total length of this path of circulation is about 7,000 miles and the average velocity of the current is about 8 miles a day. This gives a period of 2.4 years for a change from warm to cold conditions in the Arctic, or 4.8 years for the complete cycle, which exactly coincide with the periodicity of ice conditions off Iceland as demonstrated by Meinardus.[3]

In regard to forecasting droughts the authors say:

> If pressure becomes persistently low over the Arctic regions, especially at Spitzbergen, the possibility of an approaching drought must be considered. If pressure is also low over the Tropics the chances are somewhat greater, especially if the position in the 11-year solar cycle is favorable and 4 years have elapsed since the last drought. If under these conditions pressure becomes high over the Urals or northern Russia, it appears highly probable that a drought will set in within the next few months. Unfortunately the last source of information is still closed to us.
>
> The conclusions reached in this paper require to be verified and extended by a similar study of exceptionally rainy periods.

DISCUSSION.

In the discussion that followed, Dr. G. C. Simpson made the interesting suggestion that an increase in the velocity of the whirl about the poles would result in a fall in pressure in the center and a rise on the margins. Thus, when the vortex in the atmosphere in the northern regions becomes intensified, the pressure in the polar regions is decreased while that in the surrounding belt is increased. This causes the Azores high pressure to move farther north and the movement of this high pressure alters the whole of the climatic conditions of England.

Doctor Simpson also remarked that the place to look for forecasts and the mechanism of the whole thing was in the upper atmosphere where the whirl is to be found. He also remarked that probably it would be found that the pressure changes are not localized in that part of the world in which the rainfall shows the greatest abnormalities.

[3] Ann. Hydrogr. Berlin, 34, 1906, pp. 148, 227, 278.

BRIEF DESCRIPTION OF A NEW DIAL FOR THE ANEROID.

By JOSÉ CARLOS MILLÁS, Director.

[Observatorio Nacional, Habana, Cuba, June 20, 1922.]

Facing always the difficulties of obtaining good observations from untrained observers, the idea of changing the usual dial of the aneroid barometer for a simpler one, such as could be read without trouble and without training, presented itself as a solution to the problem constantly encountered by the Observatorio Nacional of Cuba.

When a meteorological service has to depend on observations made by nontechnical observers, the greatest pains should be taken to insure accuracy with *the least possible* labor to the observer. Our experience of many years in receiving daily telegrams from such a class of observers compelled us to use the aneroid with the new dial.

The instrument for this purpose should be a good aneroid, with as large a dial as possible. All division lines are absent. Instead, a system of short words is inserted, say for every millimeter of pressure. In our instruments the circle described by the index hand is about 5 inches in diameter. The words were not well placed by the printer, as those dials were printed on bristol board; therefore, we had to determine the exact value of the space from word to word. (See fig. 1.)

These short words are so chosen that no confusion whatever is possible in the telegraphic transmission of the message. The observer sends the word nearest to the index or, if it falls between two words, both are sent at the same time as one word. In this manner, the instrument reads to half a millimeter (0.02 inch). Before reading, the observer should tap the instrument lightly. In our dials we place a sign that says: *Golpear el cristal antes de leer;* the observer on facing the instrument reads that the glass should be tapped lightly before reading, *a most necessary operation* with this class of instruments. This is the only weak point of the barometer, as the observer may forget to tap it lightly before reading. To avoid this, the instrument could be placed in a case with a small door, and a mechanism attached to it so that the instrument would be tapped mechanically by the opening of the door. Then the only thing the observer would have to do would be to read the word or words.

We take away the hand-moved index that usually accompanies this class of barometers; it is not needed and may introduce errors. The correction screw is covered so as to make the barometer foolproof.

The instruments are sent well packed to the observer with a small spike and instructions for mounting it, which in our case are the following:

INSTRUCTIONS FOR MOUNTING THE BAROMETER.

1. Mark your height on the wall where the instrument is to be placed.
2. Nail the small spike 8 centimeters above the mark, so as to place the center of dial at the same height of your eyes.

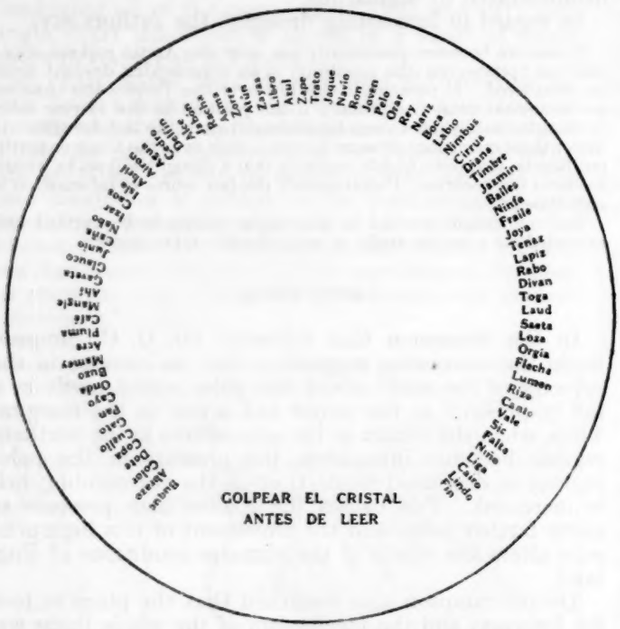


FIG. 1.—Dial for aneroid barometer used in the Cuban Meteorological Service.

Besides, in the letter to the future observer we recommend to him to place his head in such a position that he may see by reflection his eyes in the instrument, avoiding as far as possible parallactic errors.

The instruments are sent to any place without knowing the height above sea level. In fact, we do not care about this, as measures will be expressed finally to correspond to those of mercurial barometers, corrected for temperature, sea level, and normal gravity.

Of course, we have to depend on readings of mercurial barometers for the determination of the constant of each instrument. We proceed in the following manner:

Readings are taken at 7 a. m. and a value is assigned to the word sent each day from the isobar that crosses the place of the observer. In normal weather, 20 observations will suffice to eliminate all errors of drawing of isobars and give a very approximate value for a chosen word. For instance, suppose the observations sent are the following:

[Distance between words=1 mm.]

	Words received.	Value assigned.	Reduction to a chosen word on the basis of each value assigned.
June 1	toga	762.5	toga=762.5
June 2	togalaud	763.1	toga=762.6
June 3	laud	763.7	toga=762.7
June 4	toga	762.1	toga=762.1
June 5	divan	761.8	toga=762.8
June 6	divanrabo	761.1	toga=762.6
June 7	rabo	760.0	toga=762.0

The mean of 20 readings will give a fair value for the reading "toga" at this special place. Then all other values for the station are inserted and the instrument can then render service. Other determinations of the constant for the word chosen can be made from time to time.

We have found this to be the most economical and exact procedure of obtaining air pressure observations from nontechnical observers.

It might be mentioned that this device of introducing the code directly in the instrument could be utilized also in wind direction and velocity. We intend to do so in the future.

In developing this system the writer had the valuable assistance of Mr. Miguel Gutierrez Cenizos, observer of the Observatorio Nacional of Cuba.

THUNDERSTORMS OF JULY 13, 1922, IN THE DISTRICT OF COLUMBIA, MARYLAND, AND VIRGINIA.

By ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, D. C., August 15, 1922.]

The series of thunderstorms that occurred on July 13, 1922, as well as others which have been experienced during the present season, clearly lacked the usual evidence of a definite movement from one point of the compass to another that is a characteristic of thunderstorms in this vicinity. It has seemed rather that the storms have developed directly over the city and spread locally from that point as a center. The usual progression of thunderstorms in the vicinity of Washington is from the northwest to the southeast.

The object of this note is to ascertain whether the usual statistics on the occurrence of thunderstorms in the adjoining States of Maryland and Virginia would throw any light of a definitive character upon the progression of the thunderstorms of July 13, 1922.

Meteorological conditions.—At 8 a. m. of the date in question a trough of low pressure stretched from the mouth of the St. Lawrence southwestward to the Carolinas. This trough was flanked on either side by higher pressure, the level of the barometer at the center of the respective anticyclones being 30.30 inches. The winds were south to west in the trough and northerly on its western margin. The temperature at 8 a. m. at Washington, Baltimore, and in southeastern Pennsylvania was 80° or above and the humidity was relatively high, both conditions being favorable to the development of thunderstorms later in the day.

The beginning of the storm at Washington, D. C.—The first thunder was heard at 4 p. m. and rain began 5 minutes later. The local sky signs, however, indicated that preliminary thunderstorm activity had been in progress over the city for at least an hour. At 3:05 p. m. thunder was heard to the east of the station, but further development of this disturbance ceased. At 3:30 p. m. typical thunderstorm clouds appeared to the southwest and these thickened and apparently moved to the east; meanwhile the northwestern segment of the sky was devoid of thunderstorm clouds, although shortly before the storm broke a confused mass of clouds appeared in that part of the sky. At about 4 p. m. the electrical display, which had hitherto been confined to the south and east, appeared in the northwest and very quickly thereafter

rain began. The winds before the storm were from the northwest and north, occasionally backing to northeast. Heavy rain began at 4:43 p. m. with the wind in the southeast; the rain slackened somewhat about 5 p. m. and the wind shifted to northwest, rain again becoming very heavy. From 4:43 to 5:43 p. m., 2.79 inches of rain fell, being the greatest amount for an hour ever recorded at the station. The total for the storm was 3.37 inches.

Inquiry as to the amount of rainfall at near-by points in Virginia appeared to show that the intensity of the storm in that State was much less than in the District of Columbia. At this juncture it was decided to make an inquiry as to the depth of rainfall and the progression of the storm in the adjoining States of Maryland and Virginia. The section directors for those States have supplied me with data on both points and I have fortunately been able to secure from the sewer department of the District of Columbia rainfall records for the storm as measured at 24 points, mostly within the populated area of the city of Washington. These records, in addition to two others maintained by the Weather Bureau, will give a distribution approximately of one rainfall station for each square mile of territory. Mr. J. B. Gordon, sanitary engineer, has supplied a sketch map of Washington upon which I have plotted the rainfall of the storm. (See Fig. 1.)

The catch of each gauge has been entered directly upon the map in the position occupied by the gauge. It will be seen at once that there were two areas of heavy rains one in the northeastern suburbs, as at Bennings, and the other in the southwest in the Rock Creek region. Between the two there is an area of diminished fall extending in a NNE-SSW direction with the minimum fall 1.85 inches at Congress Heights.

The least catch was but 65 per cent of the average for the District and the greatest was 139 per cent of the average, or a range from 39 per cent above to 35 per cent below, and this is probably not far from the normal expectancy in similar cases. So far as known, the only other point at which excessive rains fell in a short time was at Aberdeen, Md., and at Richmond, Va. The results shown on Figure 1 are of direct interest to city engineers and others interested in sewer construction.[1]

Progress of the storm.—It is not often possible to trace a single thunderstorm across a State, and the thunderstorms of July 13 were no exceptions to the rule. On the date in question at least two series of thunderstorms were observed, the first beginning in the extreme western counties of Maryland as early as 11 a. m. and progressing eastward or developing irregularly farther and farther east, the second apparently developed about 3:30 or 4 p. m., just west of Frederick County and progressed eastward and southward rather slowly until it reached Delaware Bay between 7 and 8 p. m.

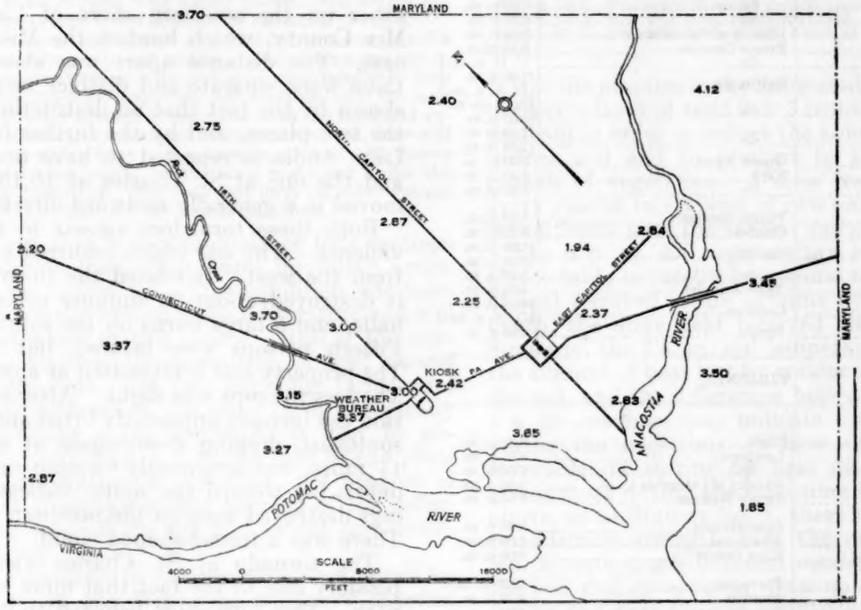


FIG. 1.—Precipitation in Washington, D. C. (inches), July 13, 1922.

In Virginia the earliest time of beginning was 3:20 p. m. at Mount Weather, in the extreme northwestern part of the State. In Loudoun County, directly east of Mount Weather, two stations report the beginning as at 4 p. m. At Washington, D. C., about 60 miles directly east, the beginning was at 4:05 p. m. Thunderstorms also began at the same hour at Charlottesville and Hopewell, Va., both points being in the south-central part of the State.

The times of beginning in both Maryland and Virginia points is shown in Table 1 on next page:

[1] Cf. The distribution of rainfall over restricted areas. MO. WEATHER REV., 49: 401-404.

TABLE 1.—*Time of beginning of thunderstorms in Maryland and Virginia, July 13, 1922.*

MARYLAND.

Station.	County.	Time of beginning.
Northern group:		
Friendsville	Garrett	11:00 a. m.
Frostburg	Allegany	1:00 p. m.
Cumberland	do	12 noon
Clear Spring	Washington	2:30 p. m.
Chewsville	do	4:00 p. m.
Keedysville	do	4:00 p. m.
Frederick	Frederick	4:45 p. m.
Emmitsburg	do	4:45 p. m.
Westminster	Carroll	2:00 p. m.
Freeland	Baltimore	2:00 p. m.
Darlington	Harford	9:30 p. m.
Falston	do	8:00 p. m.
Aberdeen	do	7:15 p. m.
Wilmington, Del.	New Castle	5:40 p. m.
Cecilton	Cecil	5:00 p. m. D. N. p. m. [1]
Middle group:		
Boyds	Montgomery	3:00 p. m.
Great Falls	do	4:30 p. m.
Takoma	do	4:30 p. m.
Washington	District of Columbia	4:05 p. m.
College Park	Prince Georges	5:15 p. m.
Laurel	do	D. D. p. m. [1]
Woodstock	Baltimore	2:50 p. m. D. N. p. m. [1]
Riderwood	do	D. D. p. m. [1] 6:00 p. m.
Baltimore	do	2:40 p. m. 7:03 p. m.
Sudlersville	Queen Anne	7:00 p. m.
Rock Hall	Kent	7:30 p. m.
Dover, Del.	do	5:30 p. m.
Southern group:		
Cheltenham	Prince Georges	4:30 p. m.
La Plata	Charles	5:30 p. m.
Ferry Landing	Calvert	4:00 p. m 6:30 p. m.
Solomons	do	5:20 p. m.
Annapolis	Anne Arundel	5:00 p. m.
Ridgely	Caroline	6:00 p. m. D. N. p. m. [1]
Seaford, Del.	Sussex	4:30 p. m.

VIRGINIA.

Northern group:		
Mount Weather	Clark	3:20 p. m.
Lincoln	Loudoun	4:00 p. m.
Arcola	do	4:00 p. m.
Washington	District of Columbia	4:05 p. m.
Quantico	Prince William	4:55 p. m.
Middle group:		
Fredericksburg	Spotsylvania	5:30 p. m.
Charlottesville	Albemarle	4:00 p. m.
Mount Moriah	King George	6:00 p. m.
Southern Group:		
Columbia	Fluvanna	12:20 p. m.
Richmond	Henrico	6:40 p. m.
Hopewell	Prince George	4:00 p. m.
Runnymede	Surrey	5:00 p. m.
Newport News	Isle of Wight	7:30 p. m.
Langley Field	Elizabeth City	9:00 p. m.
Norfolk	Norfolk	2:20 p. m. 7:10 p. m.
Cape Henry	Princess Anne	1:40 p. m. 7:30 p. m.

[1] D. N.=During night; D. D.=During day. The stations are arranged according to geographic position beginning in the extreme northwest and proceding due east, then returning to the west and proceding east as before.

The evidence of the above table is not conclusive either for or against the idea of nonprogressive movement; it, however, seems to support the belief that thunderstorms developed east of the Blue Ridge in both Maryland and Virginia at approximately the same hour on the afternoon of the 13th and that the more vigorous of them moved east-southeast or due east. It is also clear that there were at least two distinct series of storms in both States and that the second one was the more violent of the two. The concentration of the heavy rainfall in one or two localities must be explained as due to local and favorable conditions at those points. Very heavy rain also fell in Maryland on the 20th, due to a barometric depression central on that date on the coast.

TORNADOES IN SOUTH DAKOTA, JULY 8, 1922.

By M. E. BLYSTONE.

[Weather Bureau, Huron, S. Dak.]

In the evening of July 8, 1922, two tornadoes occurred in rather close proximity near the southern border of South Dakota, one at St. Charles, Gregory County, which borders the Missouri River on the west, and the other on the southern shore of Lake Andes, Charles Mix County, which borders the Missouri River on the east. The distance apart was about 30 miles. That these were separate and distinct tornadoes seems to be shown by the fact that no destruction occurred between the two places, and by the further fact that the one at Lake Andes is reported to have occurred at 10 p. m. and the one at St. Charles at 10:15 p. m., while both moved in a generally eastward direction.

Both these tornadoes appear to have been of great violence. The one which occurred at Lake Andes came from the west. It missed the town of that name, but it destroyed about 20 summer cottages, 2 large dance halls, and 5 large barns on the south shore of the lake. Fifteen persons were injured, but no one was killed. The property loss is estimated at approximately $25,000. The loss to crops was slight. After causing this destruction the tornado apparently lifted and moved toward the southeast, dipping down again at a distance of about 1½ miles, but apparently causing no destruction. The débris lay toward the south, indicating that the buildings destroyed were on the northern side of the tornado. There was a funnel-shaped cloud.

The tornado at St. Charles was more destructive, possibly due to the fact that more buildings were in its path. This tornado is believed to have originated near Brocksburg, Nebr., about 15 miles southwest of St. Charles, where some barns were destroyed. However, it appears to have caused practically no destruction in South Dakota except at and near St. Charles. Practically all the buildings in St. Charles were destroyed or damaged. One grain elevator was upended and practically destroyed. Another near it was damaged only slightly. One lumber yard was destroyed and the lumber scattered. The total property loss is estimated at $150,000. One person was killed and nine were injured. There is no report that a funnel-shaped cloud was seen, probably due to darkness, but as the path of destruction did not extend beyond the limits of the town there seems to be no doubt but that the storm was a tornado.

INFLUENCE OF VARYING SOIL CONDITIONS ON NIGHT-AIR TEMPERATURES.

By E. H. HAINES, Meteorologist.

[Weather Bureau, Chicago, Ill., March 20, 1922.]

SYNOPSIS.

A relation shown to exist between the temperature of the soil and the ensuing minimum temperature of the air immediately above, as affected by the varying conditions of the former—constituent character of the soil, moisture content, and the amount and character of the vegetal cover. Low night-air temperatures in gardens and truck farms may often be prevented in the first place by the selection of soil in which there is a sandy component, as sand and sandy loams are warmer than other soils and give off heat in the nighttime by conduction to the air above, thus diminishing the probability of critical temperatures and the formation of damaging frosts. Secondly, the land in use should be well drained of surplus moisture, as wet soils are invariably cold soils and more susceptible to frost damage. Lastly, any soil, whether it be sand, loam, or clay, is warmer when it is clean and free from weeds and unnecessary vegetation, as bare soils are productive of higher night-air temperatures than those covered with a rank growth, from which the heat received in the daytime is lost at night by radiation to space.

Finally, there may be several reasons why frost forms on one side of a street and not on the other, or in one section of a level farm and not in another. If there are contrasting soils, one producing relatively high night-air minima and the other relatively low readings, or if the land differs even slightly in the amount of moisture, or in the kind and extent of the surface covering, or amount of insolation received, frost will appear in the sections which have wet, cold soils, covered with heavy vegetation or uncultivated, while, on the same night and under the same meteorological conditions, frost may not form on other ground close by where the soil is relatively dry, warm, and clean.

It is well known that in mountainous or hilly sections on clear, cool nights frost often forms on valley floors, but not on slopes higher up. This condition has been discussed extensively in meteorological literature and will not be given attention in this article. Rather the subject of differing night-air temperatures on *level ground* will be considered here. On two adjoining farms, and even in different portions of the same farm, practically level, widely differing night temperatures may be observed, resulting sometimes in a killing frost in one place and favorable temperature in the other; not because of any difference in topography, but because of the differences in the character of the soil and extent and condition of its covering.

Remarkable variations in temperature were noted by Prof. H. J. Cox [1] in the Wisconsin cranberry marshes during an investigation conducted there in the seasons of 1906–7; and, as the bogs where the observations were made are absolutely level, the results of this study may be applied to ordinary level farm land. The differences in temperature noted in the Wisconsin investigation were found to be largely due to the variation of the temperature of the soil as determined by the varying conditions with respect to the kind of soil, its moisture, and the amount and character of its vegetal cover. Concerning these variations Professor Cox says:

> On any clear, cool night the cold air overspreads the bog, and here and there are found warm places and cold places and others having intermediate values, depending upon the character of the soil and its covering. It is as if heaters of varying power were scattered over the bog, giving off heat to the air immediately above, some in greater quantities and others in less.

The following condensed table from Bulletin T strikingly bears out the above statement, and shows the average variation in temperature as registered by thermometers placed at the surface of the ground and at a depth of 3 inches at four locations in the Appleton Marsh at Mather, Wis., during the crop season of 1907, these exposures representing various conditions of soil and vegetal cover found in the marshes:

	Station—			
	No. 1.	No. 2.	No. 3.	No. 4.
	°F.	°F.	°F.	°F.
Soil temperature, 6 p. m., 3-inch depth	62.6	58.0	56.6	57.2
Soil temperature, 7 a. m., 3-inch depth	54.4	54.9	55.1	54.9
Loss of temperature by soil during night	8.2	3.1	1.5	2.3
Exposed minimum at surface of ground during night	45.5	43.0	41.7	42.3

Station No. 1.—Peat soil with sanded surface; vegetation thin.
Station No. 2.—Peat soil with sanded surface; vegetation heavy.
Station No. 3.—Peat with moss; vegetation heavy.
Station No. 4.—Peat soil, sanded, with 1 inch of new peat on surface; vegetation heavy.

It is the practice in the more modern cranberry marshes to place a layer of sand 2 or 3 inches in thickness over the peat soil in order to reduce the amount of moisture in the surface soil and to prevent to a certain extent rank growth of vegetation. Unless resanding is resorted to every year or two a layer of new peat from decaying vegetation forms over the sanded surface.

The 6 p. m. soil temperature readings shown in the above table naturally bear some relation to the amount of heat received in the daytime by the soil at the 3-inch depth, the more heat received the higher the reading. Similarly, the 7 a. m. soil temperatures bear a relation to the amount of heat lost by conduction and radiation from the soil, and the differences between the 6 p. m. and the 7 a. m. readings may indicate the amount of heat lost during the nighttime. Where the soil conditions are favorable for storing up heat during the daytime and giving it off during the nighttime to the air immediately above, as at Station No. 1, there is found a "heater" of considerable strength. On the other hand, at Station No. 3, with much different conditions, the character of the soil and its covering does not permit much heating during the daytime and consequently there is little heat to give off at night. There we may say is located a "heater" of low power. The higher average minima of 45.5° at the surface of Station No. 1 compared with the relatively low average of 41.7° at the similar location at Station No. 3 show the remarkable effect of the soil and vegetal cover upon night-air temperatures immediately above the surface of the ground. The readings at Stations No. 2 and No. 4 show results intermediate in value between the extremes at Stations No. 1 and No. 3, depending upon whether the conditions of soil and cover lead to relatively high or low afternoon soil temperatures and later correspondingly high or low night-air minima.

The degree of fall in air temperature during the night depends largely upon the warmth of the soil. Where the amount of heat absorbed during the day is slight and the ensuing night calm and clear, thus permitting rapid cooling by radiation, the result is a low night-air temperature. On the other hand, where a large amount of heat is absorbed during the day by the soil, there can be more heat lost from the soil to the air above before a critical temperature is reached, simply because there is a greater amount of stored heat to draw upon. Although these conclusions are based upon observations made over

[1] Cox, H. J.: Frost and Temperature Conditions in the Cranberry Marshes of Wisconsin, *Bulletin T*, U. S. Weather Bureau, 1910.

marsh land, they may apply with equal force to conditions which are frequently found over level farm land.

Franklin's [2] observations made in 1918–19 in England, covering temperatures taken at the surface of the soil and at a 4-inch depth, "uphold," he says, in referring to Cox's investigation in the Wisconsin marshes, "the view that the temperature and conductivity of the soil play a most important part in determining the minimum temperature at night."

It is now a generally accepted fact that the character and temperature of the soil do affect to a marked degree night-air temperatures up to a height of several inches above the surface, and this influence should not be overlooked in connection with the occurrence of frost on level ground where truck is raised or where berries are grown on vines or small bushes. Of course, on very still nights, at a distance of several feet above the ground, the influence of soil conditions is lost or nearly lost, and it is therefore not a factor in the discussion of methods of protection from frosts in orchards, except for small fruits.

The writer, who was privileged to take part in the Wisconsin research, believes that the knowledge of the relation of soil conditions gained in that study to air temperatures immediately above, might well be applied to general farm land. Moreover, it is hoped to meet the statement so often made that frost is observed on one side of the street and not on the other *without any apparent reason*. The results of the investigation in the cranberry marshes were most beneficial, and the methods now practiced by the growers to avoid damage from frost—sanding, draining, and cultivating—will be discussed in order in connection with their value as an aid in warding off frost where truck or fruit grow near the ground.

ADVANTAGES OF SANDY SOILS.

Sanding, as previously stated, is resorted to in some localities in the laying out of the more modern cranberry marshes in order to reduce rank vegetable growth and surface moisture, and thus prevent low night-air minima. Of course, it is impracticable to sand large or even small areas of ordinary farm land for the purpose of warding off frost, but it is nevertheless well to point out the advantages of sandy soils, so far as heat conservation is concerned, in order that these facts may be of assistance in the selection of ground for the growing of truck and small fruits.

Sand is formed from the disintegration of rock and consists of relatively coarse rock particles. Clay is also formed from the disintegration of rock and differs from sand in that it contains the largest proportion of fine particles of any soil, while sand contains relatively large particles. Loams, strictly speaking, consist of earthy matter composed largely of either sand or clay, but having enough of the former to counteract the cohering property of the latter, and contain particles intermediate in size between those of sand and clay. They also include a considerable amount of decayed organic matter, pure black loam having a larger proportion of decayed vegetation than either sandy loam or clay loam, and it is therefore a poorer conductor of heat. Peat is a carbonaceous matter formed by the partial decomposition of plants in water, and is, of course, also a poor conductor of heat, much poorer than loam even.

Of the soils mentioned, peat is probably the best radiator and sand the poorest, with loams and clays occupying intermediate positions. Pure black loam, however, is undoubtedly as good a radiator as peat. Sand gives out heat slowly, and cools mainly by conduction to the air immediately above, instead of by radiation through the air as do loam and peat. Night-air temperatures over sand and soils mixed with sand are therefore relatively high.

Black soils, of course, are excellent absorbers of heat, and peat, black loam, clay, clay loams, sandy loams, and sand rank in the order named in their absorptive power. A black loam is colder than a sandy loam, however, because, although more heat is absorbed during a sunshiny day, the degree of conduction into the soil and consequent storing up is not so great and more is lost at night by radiation.

Prof. W. J. Humphreys[3] says:

> The better the absorber, other things being equal, the warmer it gets during insolation and the more it heats the air, while the better the radiator it is, the colder, as a rule, it and the air adjacent become during the night. When the atmosphere is clear and dry, and therefore diathermanous, the cooling of objects and their liability to frost depend largely upon their capacity to radiate at ordinary temperatures. A good radiator under these conditions loses heat partly by radiation through the atmosphere to space. It cools rapidly, but the heat it gives off does not all go to warming the air, for a part of it is directly lost to space. On the other hand, an object that radiates poorly gives off its heat in a large measure by conduction to the atmosphere. It tends to conserve both its own temperature and that of the surrounding air and thereby diminishes the probability of frost.

Since one of the chief factors in influencing the temperature of a soil is its capacity for water and as sand retains only a small proportion of moisture when all the free water has been allowed to drain away, it should be apparent that soils having a sandy component, and therefore relatively free from excess moisture, are productive of higher night-air temperatures than those containing more moisture. Sand because of its low capillarity prevents water in the ground from coming to the surface. It also warms easily because of its low specific heat. As a result of these characteristics sand conserves both its own temperature and that of the surrounding atmosphere, thereby diminishing the probability of frost. It is for these reasons in addition to ease of cultivation and quick drainage that truck growers prefer a sandy soil—either sand or sandy loam—especially for early garden crops.

It should be stated, however, that, while a sandy component in a soil is instrumental in modifying low night-air temperatures, this influence is of little consequence after frost has once entered it. This fact was quite apparent as a result of the Wisconsin study, inasmuch as the differences between the exposed minima over sand and peat were small during the month of October as compared with those in the warmer months.

Professor Cox found in the cranberry research that for the two months of August and September, 1906, the average minima 5 inches above the surface of sanded portions of the Appleton and Fitch marshes were, respectively, 4.4° and 5.4° higher than the minima at similar exposures over peat, some daily differences between these locations being as great as 19°.

Other investigators, also, in soil temperature have found sandy soils to be much warmer than other soils. King [4] compared the temperature of a well-drained sandy loam with that of a black marsh soil and found that the former averaged for five consecutive nights 7.5° warmer than the latter, this difference being sufficient to have a most decided effect upon crops.

[2] Franklin, Capt. T. Bedford: The Cooling of the Soil at Night with Special Reference to Late Spring Frosts (II), Proceedings of the Royal Society of Edinburgh, session 1919–20, Vol. XL, Part I (No. 2).

[3] Humphreys, W. J.: Bulletin of the Mount Weather Observatory, Vol. II, part 3.

[4] King, F. H.: The Soil.

O. G. Malde, for many years in charge of the branch experiment station in the cranberry bogs at Cranmoor, Wis., in an unpublished article, writes as follows:

Temperature data recently compiled as a summary of 11 seasons of observations at the Cranberry Experiment Station (1906 to 1916, inclusive) show that there is an average of 58 days between the last spring and the first fall frost (June 25 to August 22) over unsanded bogs, as against 118 days between last spring and first fall frost over sanded bogs. This represents a gain of 95 per cent in length of frost-free season on sanded bogs over that on unsanded bogs. The item of sanding, therefore, greatly reduces frost hazards and conserves the water supply by eliminating the need for frequent flooding to protect against summer frosts. Sanding also permits, and, in fact, requires, deeper and better drainage, and is an insurance against fires on bogs in dry seasons.

The soil in many orchard regions is of sand, as in western lower Michigan, and fruit may be raised on such a soil to advantage. Along the Atlantic coast, Norfolk sand is considered one of the best soils for the growing of truck, while the sandy loam found in many agricultural regions shows the advantages of the sandy component. The volcanic ash of the far West has some qualities similar to sand so far as its heating property is concerned.

When the statement is made that frost without apparent reason is noted in one section of a level farm and not in another, it is now seen that there is a reason and that it may be a question of character of soil, sand and loams with a sandy component being productive of higher night-air minima than black loams, clay loams, and clay.

DRAINING.

Frost occurs more frequently on wet or damp ground than on dry ground, and this is true irrespective of the character of the soil. In the Wisconsin investigation it was found that for the month of September, 1906, in the Fitch Marsh near Berlin there was an average difference of 2.4° between the minima at the surfaces of wet sand and dry sand in locations only 50 feet apart, the soils otherwise being the same so far as vegetal cover was concerned. The average minimum over the dry surface was, of course, the higher. This average included all nights, whether clear, cloudy, or rainy, and the difference was naturally most marked on clear nights; on one such night the thermometer over the dry surface registered 35.8° and over the wet 27.3°—a most remarkable variation of 8.5°, with safety at one point and damaging frost at the other. Since these two surfaces were located in the same section of the bog, distant from each other not more than 50 feet, and there was no difference in the character of the soil cover, as stated previously, the larger amount of moisture present was solely responsible for the relatively low value over the wet surface. The amount of this variation represents roughly the margin of safety which may be assumed to obtain on radiation nights between dry and wet sanded surfaces; but the differences would probably not be so great over loams or clays, as the range in surface temperature over sand is large owing to its low specific heat.

Gardens, fields, and farms well drained are less susceptible to frost than lands poorly drained and having a surplus of moisture, other conditions being equal, as a dry soil is productive of higher night temperatures. This is because part of the sun's heat is used in evaporating moisture from a wet surface and raising the temperature of the water in the soil, while the same amount of heat in falling upon a dry surface more directly affects the soil. Five times as many heat units are required to raise the temperature of 100 pounds of water 1° F. as are required to raise the temperature of a similar amount of dry soil 1° F. Wet soils are always relatively cold because evaporation of their water content keeps their temperature low. This lowering of temperature by evaporation is in proportion to the rate at which evaporation occurs. King [5] shows that the difference in the rate of evaporation from clay and sandy soils when both are well drained is often sufficient to produce a lower minimum by 7° in the clay at a depth of 1 foot. This difference would, of course, be greater at the surface of the two soils, and cause a corresponding difference in the air temperatures immediately above the surfaces. Clay soils are relatively cold because of the large amount of evaporation from the surface, the water capacity of clay being about 40 per cent, while some sandy soils and loams that are warmer than clay may have a water capacity as low as 5 per cent. King states that a given amount of sunshine that will heat a certain quantity of water 10° will raise the temperature of an equal amount of dry sand 52° and of clay 44°. A well-drained soil is not only generally warmer than a damp soil but it is easier to work, and the number of days that it can be worked is also much greater.

In the cranberry marshes ditches, run at frequent intervals, serve to carry away surface moisture and reduce evaporation; and ditching and tiling are resorted to in the draining of truck lands.

Here we find another reason to account for the appearance of frost on certain portions of level land and not on adjoining sections—that of drainage, a deposit of frost being more likely to form where the soil is moist, because such soil is likely to be relatively cold than where it is drier.

CULTIVATING.

In the Wisconsin research it was also found that vegetation, as well as the character of the soil and its moisture, is a most important factor in affecting night-air minima immediately above the surface of the ground. Where there is dense vegetation the soil temperature is kept from reaching a high point in the daytime, since the surface of the ground is then screened from the sun's rays; and, inasmuch as leaves and grasses are excellent radiators and lose heat rapidly, especially when the atmosphere is diathermanous, crops with heavy foliage are more subject to damage from frost than those with thin foliage, other considerations being the same. In dense vegetation and weeds, then, are found high day and low night temperatures.

Now, on the other hand, relatively low temperatures during the daytime and relatively high temperatures at night are found in the air immediately above a bare, clean soil or even one thinly covered with vegetation. The direct insolation is chiefly absorbed by the clean soil and conserved, and given off to the air above at night, largely by conduction, if the soil be sandy, thereby preventing frosts and low minima. But whether the soil be sand or loam or clay, the cleaner it is the warmer it becomes through insolation and the higher are the night-air temperatures above.

The above statements are in harmony with the values contained in the table below, showing the average maximum and minimum temperatures at the surface of the marsh for the crop period from May to September, inclusive, 1907, at the Appleton Marsh, Mather, Wis., at the two stations having contrasting conditions as regards

[5] King, F. H.: Irrigation and Drainage.

covering, but similar environment as regards soil and moisture.

	Station—	
	No. 1.	No. 2.
	° F.	° F.
Average maximum temperature at surface in open	89.1	96.6
Excess at No. 2		7.5
Average minimum temperature at surface in open	48.8	46.1
Excess at No. 1	2.7	

Station No. 1.—Peat soil with sanded surface; vegetation thin.
Station No. 2.—Peat soil with sanded surface; vegetation heavy.

The above data, of course, represent average values, including cloudy weather as well as clear, but it is during clear weather naturally, when critical temperatures are most likely, that the advantage of bare soil over dense growth is most apparent in the resulting temperature conditions. In several instances during the cranberry marsh research the maxima in dense vegetation under the most favorable conditions exceeded that over bare soil by from 10° to 15°, the minima the following morning in the rank growth being from 5° to 8° lower.

PREDICTING MINIMUM TEMPERATURES IN THE VICINITY OF WALLA WALLA, WASH.

By CHARLES C. GARRETT, Meteorologist.

[Weather Bureau, Walla Walla, Wash., August 14, 1922.]

Beginning with the spring frost season of 1915, a localized frost-warning service has been maintained at the Weather Bureau office at Walla Walla, Wash., for the benefit of orchardists and truck gardeners in various districts of southeastern Washington and northeastern Oregon. At one time the district included orchard sections as far away as the Umatilla irrigation project, near the junction of the Umatilla and Columbia Rivers in Oregon, and the White Bluffs project, on the west bank of the Columbia north of the mouth of the Snake River, but the area has been diminished considerably in the last two or three seasons.

As is the case in all of the commercial fruit-growing regions, the extent of orchard-heating operations for the purpose of combating frost is largely dependent upon local economic conditions, and interest in the matter increases and diminishes following seasons with greater or less frost damage.

The cost of installing orchard-heating equipment and the cost of fuel-oil and extra labor of filling and lighting the containers add materially to the running expenses of an orchard. If the prices received by the growers for their products are low, many do not consider that it pays to go to the extra expense of equipping their orchards with frost-fighting devices. Particularly is this true in a region similar to the Walla Walla Valley, which is usually quite free from severe frost damage. In the last two or three seasons heating has been confined mostly to prune and a few peach and cherry orchards. Practically no effort is now made to heat the large commercial apple orchards anywhere in the district. The question as to the effectiveness of orchard heating, when properly carried on, is not now often raised in this district, as it has been quite conclusively demonstrated by a number of prominent orchardists that the temperature within a heated orchard can be raised several degrees above that on the outside. The only question is that of the desirability of going to the extra trouble and expense.

Even though the number of orchardists in the Walla Walla district who are prepared to smudge or heat their orchards is relatively small, a considerable demand exists each season for accurate forecasts of minimum temperatures on critical nights for the fruit. A forecast merely of light, heavy, or killing frost, while of value, is not sufficient.

In addition to a careful study of the morning and evening weather charts, the methods of forecasting minimum temperatures are based primarily on readings of a maximum thermometer and readings of dry and wet bulb thermometers taken, preferably, in the early evening. The instruments should be exposed in a ground shelter under conditions approaching as closely as possible those existing in the orchards.

Studies of different methods have been made by a number of investigators, and explanations published in various numbers of the MONTHLY WEATHER REVIEW,[1] and in MONTHLY WEATHER REVIEW SUPPLEMENT No. 16.

(*Method A*) *Dewpoint-relative-humidity charts.*—This method is based on the well-known relationship between evening hygrometric data and ensuing morning minimum temperature. On a comparatively calm, clear night a knowledge of the value of the evening dewpoint enables one to approximate the minimum temperature of the following morning provided the relative humidity is taken into consideration along with the dewpoint. The depression of the minimum temperature below the evening dewpoint is greater when the moisture content of the air is low than in the case where there is a greater supply of moisture. If the relative humidity is comparatively low the dewpoint will be reached later in the night, if reached at all, than if the relative humidity is high. To best utilize the observations of dewpoint and relative humidity in the practical work of forecasting minimum temperatures it has been found convenient to chart the observations on cross-section paper. The relative humidity data are indicated at the bottom of the chart, while figures at the left indicate the differences between the dewpoint at the evening observation and the minimum temperature of the following morning. A dot is entered on the diagram to agree with the observed relative humidity and the variation of the minimum from the dewpoint temperature.

Dot charts have been prepared at the Walla Walla station, one for the first and one for the last half of the spring-frost season. Data for all the clear and mostly clear nights for several seasons were used—a period long enough to afford a fair test of the practical value of the method. On the Walla Walla charts the dots arranged themselves in the form of a parabolic curve. The curve of nearest fit through the dots was calculated by the "star point method." A full explanation of the process employed for calculating the curve is given by Prof. J. Warren Smith in MONTHLY WEATHER REVIEW SUPPLEMENT No. 16. Where many observations are available for making the dot charts the line or curve of nearest fit may be drawn with fairly good results free-hand instead of making use of a mathematical calculation.

By the use of the charts the forecaster, knowing the evening relative humidity and dewpoint at his station, can arrive at a close estimate of the probable minimum temperature at the "key station" on the following

[1] MO. WEATHER REV., October, 1914; August, 1917; May, 1918.

morning. The charts are of value only on comparatively clear nights, when nocturnal radiation is mostly uninterrupted. Clouds and wind, especially when they occur near the normal time of minimum temperature, serve to check the temperature drop, resulting in a higher minimum than would have been reached if the night had been clear throughout. However, errors in the forecast due to these causes are on the *safe* side; that is, the minimum that is reached is higher than the predicted minimum. Errors on the *unsafe* side (minimum lower than predicted) would result from the importation during the night of colder air from outlying regions. In the Walla Walla district, and other orchards west of the Rockies, fortunately, such a condition occurs very rarely in the spring. A close study of the evening weather map is the forecaster's recourse under such conditions. (See MONTHLY WEATHER REVIEW SUPPLEMENT No. 16.)

(*Method B.*) *Relation between maximum and minimum temperatures.*—A diagram showing the relation between the maximum temperature of the day and the minimum temperature of the following morning has also been prepared at Walla Walla, the data employed being those for the same nights used in preparing the hygrometric charts. On the maximum-minimum chart the dots fit quite closely along a straight line. The minimum temperature estimated from the diagram has fairly closely approximated the actual minimum recorded on nights of good radiation. An average of the minima indicated by the dewpoint-relative-humidity chart and the maximum-minimum chart gives very satisfactory results if clear weather prevails.

(*Method C.*) *Subtracting a constant from the evening wet-bulb temperature.*—Investigations carried on by the Swedish meteorologist Anders Ångström[2] resulted in his finding that the minimum temperature could be closely estimated by subtracting a constant from the evening wet-bulb temperature, best results being obtained when the wet-bulb thermometer was read at about sunset. Following out this suggestion, the present writer has calculated the average variation at Walla Walla for 121 nights in the six seasons 1917 to 1922, inclusive, and found it to be 10.5° for the first part of the season, March 15 to April 15, and 11° for the last part, April 16 to May 31. The greatest difference between wet-bulb and minimum was 16°, and the least 6°. By subtracting the constant of 11° for the 121 nights the minimum would have been predicted within 3°, or less than 86 per cent of the time. A comparison of the predicted minimums obtained by use of the hygrometric charts and those obtained by subtracting the constant from the evening wet-bulb temperature shows that the indicated minimums were nearly the same in every case. The Ångström method is certainly a simple and easily arrived at one of deciding on the probable minimum temperature from wet-bulb readings alone on nights of good radiation.

(*Method D.*) *Predicting the minimum temperature from the median temperature hour.*—An additional aid to the forecaster is what is termed the median temperature method. By the median temperature is meant the halfway temperature between the afternoon maximum and the ensuing morning minimum. On nights of good radiation, when meteorological factors other than the normal nocturnal fall are not involved, the median temperature falls at nearly the same time in the evening, except that the time becomes later as the season advances. It has been found at Walla Walla that the average time is about 7:40 p. m. for the last half of March, 7:55 p. m. for the first half of April, 8:05 p. m. for the last half of April, 8:15 p. m. for the first half of May, and 8:25 p. m. for the last half of May. By noting at the proper time the number of degrees fall from maximum temperature that has taken place, and subtracting that value from the current temperature, a figure that will agree fairly closely with the next morning's minimum will be obtained. The median time method, obviously, can be used only for late evening warnings. (See MONTHLY WEATHER REVIEW, October, 1914, p. 581.)

The working method at the Walla Walla station has been to average the minimum temperatures that have been estimated by the various methods, taking into consideration the observed local conditions and the general barometric and weather conditions as shown by the p. m. weather chart. Of course, blind reliance must not be placed on any formula or set of rules for predicting minimum temperatures, but the experience of those who have studied the relationship of evening hygrometric data to morning minimum temperatures, as well as the relation of maximum to minimum, and applied the result of their studies to the practical work of forecasting, taking into account other factors in their proper relation, has resulted in renewed confidence in their ability to forecast closely the minimum temperatures on critical nights for fruit and vegetable growers.

In a district where temperature conditions may vary considerably in the different local areas the aid of cooperative observers is necessary for best results. Where it is not easy to obtain uniformly reliable readings of the wet and dry bulb thermometers, due to inexperience or lack of available time on the part of the cooperative observer, a knowledge of the thermal relationship between the outlying districts and a central "key" station can be had through comparative readings of self-recording minimum thermometers, or records of thermographs, covering a period of several seasons.

In the accompanying table appear the results of using the various methods described in this paper, for a number of typical radiation nights during the four seasons 1919 to 1922, inclusive. The dates selected were all those after March 15, when heavy to killing frost occurred at Walla Walla. The table shows, in addition to the results obtained by the application of each method, the estimated minimum obtained by averaging those estimated by all the methods.

[2] Anders Ångström: Studies of the Frost Problem, 1. *Geografiska Annaler*, 1920, H. 1.

TABLE 1.—*Minimum temperature estimates for Walla Walla, Wash., on nights during the spring seasons 1919 to 1922, inclusive, using hygrometric, maximum-minimum, and median temperature methods. (Dates given in the table include all nights after March 15, with heavy or killing frost.)*

Date.	Hygrometric chart method.	Maximum-minimum method.	Constant subtracted from wet-bulb temperature.	Median temperature method.	Average of all methods.	Recorded minimum.	Difference.
1919.							
Mar. 20	34	31	31	26	30	29	+1
21	32	34	32	29	32	32	0
22	29	33	33	26	30	30	0
24	33	35	32	26	32	30	+2
25	25	28	27	23	26	29	−3
26	29	32	31	30	30	31	−1
Apr. 12	28	30	30	26	28	30	−2
15	31	33	30	28	30	29	+1
May. 4	30	31	31	34	32	31	+1
1920.							
Mar. 17	21	25	25	23	24	25	−1
1921.							
Mar. 27	28	30	28	24	28	30	−2
30	30	33	31	27	30	31	−1
31	31	35	32	27	31	31	0
Apr. 4	22	.....	26	34	27	29	−2
7	27	31	28	23	27	30	−3
8	30	32	29	29	30	30	0
9	34	37	34	26	33	31	+2
1922.							
Mar. 26	25	25	27	.....	26	28	−2
Apr. 12	28	28	26	24	26	29	−3
May 9	28	33	28	26	29	29	0

THE TEMPERATURE AT PORTO VELHO, AMAZONAS, BRAZIL.

BY ALFRED J. HENRY.

Through the courtesy of Dr. Frederick L. Hoffman, statistician, Prudential Insurance Co., the Weather Bureau has been supplied with almost 14 years of climatological observations made by the Engineering Department of the Madeira-Mamore Railway at its eastern terminal, Porto Velho, on Madeira River just above the point where navigation on that river is interrupted by rapids and falls.

The monthly totals of rainfall will appear in an early number of this REVIEW.

The temperature observations were made at the hours 6:30 and 11:00 a. m. and 3:00 and 6:30 p. m. except that the last-named hour was changed to 5:30 beginning with June, 1917. No one of these hours alone, or any combination of them which might be made, would yield results that would closely approximate the mean temperature of the 24 hours, hence the means for each separate hour have been computed and are presented in Table 1. These data give a close approximation to the daily range in temperature for each month of the year. It may be seen by simple inspection that the mean temperature rises about 10° daily from 6:30 a. m. to 3:00 p. m. during the wet season, which extends from November to May, and as much as 15°, on the average, in the winter or dry season. Since the occurrence or nonoccurrence of showers in the afternoon would have an important influence on the afternoon maximum, it is inferred that relatively dry months in the wet season would be favorable to high temperature.

The highest temperature recorded at any of the observing hours was 104° F. in October, 1914. Temperatures of 100° F. were also recorded in August and October, 1916, and in September, 1917. September is the month of greatest maxima and February the least.

The lowest temperature recorded during the period of observations was 56° F. in June, 1916, at 6:30 a. m. I have compiled from the daily observations the observed extremes for each month and present them in Table 2. The means given at the bottom of this table may be considered as approximate means of the monthly extremes from which may be obtained the average monthly range of temperature. An inspection of these mean results shows that the range is greatest in the winter months of June-August and least in the summer months of January-February.

It is interesting to note that Porto Velho temperatures were at a maximum in 1914–15, and at a minimum in 1916–17, as noted for Arequipa.[1]

TABLE 1.—*Monthly mean temperature at Porto Velho, Brazil, for the hours named, January, 1908, to November, 1921.*

[Approximate latitude 8° 44′ S., longitude 64° 00W. Elevation, —.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
6:30 a. m.	76.1	76.2	76.2	76.4	75.5	73.4	72.2	73.9	76.0	76.5	76.3	76.0	75.4
11:00 a. m.	82.1	82.1	82.8	83.2	83.6	83.1	83.9	85.4	86.3	85.2	84.2	82.5	83.7
3:00 p. m.	85.1	85.1	85.5	86.2	86.1	86.5	88.2	90.4	90.6	88.5	87.0	85.3	87.0
6:30 p. m.	82.6	82.5	82.6	83.0	83.1	83.9	85.7	86.3	86.6	85.1	83.8	82.9	84.0

TABLE 2.—*Approximate monthly extremes of temperatures for Porto Velho, Amazonas, Brazil.*

[Maxima taken mostly from observations at 3 p. m. and minima taken from the 6:30 a. m. observations.]

Year.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1908	max.	93	92	95	95	91	95	91	94	96	93	92	92	96
	min.	73	72	72	73	66	65	63	63	67	72	72	70	63
1909	max.	93	89	90	89	89	90	91	96	97	96	93	91	97
	min.	72	72	72	72	57	63	57	58	63	72	70	70	57
1910	max.	93	90	87	90	90	90	92	96	98	95	98	91	98
	min.	71	73	74	73	69	67	68	62	74	72	77	73	62
1911	Max.	92	94	91	91	92	89	94	95	97	94	94	92	97
	min.	74	74	70	71	70	58	63	66	70	70	75	75	58
1912	max.	94	94	94	91	92	90	93	94	94	94	91	93	94
	min.	75	76	74	74	71	75	58	68	68	76	75	73	58
1913	max.	92	91	92	91	90	90	94	99	97	94	95	97	99
	min.	74	75	75	74	72	70	68	66	72	74	75	68	66
1914	max.	90	90	92	93	92	94	93	96	96	104	98	94	104
	min.	74	76	74	72	68	70	71	70	73	74	72	72	68
1915	max.	93	94	96	96	96	92	95	98	95	95	93	92	98
	min.	74	72	76	74	74	62	58	70	70	74	72	71	58
1916	max.	90	90	92	92	93	92	94	100	98	100	94	90	100
	min.	72	72	72	73	72	56	66	68	68	70	64	72	56
1917	max.	92	90	91	92	90	94	96	98	100	94	92	90	100
	min.	72	70	72	72	60	65	64	62	62	70	72	72	60
1918	max.	90	87	88	89	92	92	93	93	95	95	97	94	97
	min.	71	72	72	71	59	62	67	70	73	70	71	71	59
1919	max.	94	91	93	93	96	96	96	97	97	96	96	94	97
	min.	70	75	74	72	70	66	72	60	68	72	74	75	60
1920	max.	94	92	93	92	93	95	96	96	96	94	98	92	98
	min.	76	74	76	74	74	64	66	63	65	72	73	74	63
1921	max.	93	96	92	93	94	95	95	96	98	96	.....	.....	98
	min.	76	74	74	72	73	60	60	64	64	70	.....	.....	60
Mean max.		92.8	91.4	91.9	91.9	92.1	92.5	93.8	96.3	96.7	95.7	94.7	92.4	98.0
Mean min.		73.1	73.3	73.3	72.7	69.5	64.3	64.9	64.8	68.1	72.2	72.4	72.0	60.6

[1] Cf. this REVIEW 503.

NOTES, ABSTRACTS, AND REVIEWS.

THE METEOROLOGICAL STATION ON JAN MAYEN.[1]

[Excerpt from United States Consular Reports.]

On August 1, 1921, Mr. Hagbard D. I. Ekerold, an American citizen, left Norway with two small vessels, the *Isfuglen*, 54 tons, and the *Polarfront*, 24 tons, on a meteorological and scientific research expedition to Jan Mayen's Land, a tiny island in the Arctic, north of Iceland and midway between the North Cape and the Greenland coast. The expedition was sent out under the auspices of the Meteorological Bureau of the Bergen Institute, and with the assistance of the Norwegian Government. A weather observatory, with wireless station, was erected, and Mr. Ekerold, with four assistants, spent the winter on the island. He has just returned to Norway, and has received assurance of support which will enable the station on Jan Mayen to continue as a permanent branch of the Norwegian weather service. The expedition was accompanied by a party of English scientists who studied plant and animal life on the island, and the following from an address by Mr. J. M. Wordie, a member of the party, before the British Geographical Society seems of general interest.

Discussing the results of the expedition, Mr. Wordie says that the island is apparently unremunerative commercially, but that—

the Norwegians, however, have realized its importance in another field. Their country is peculiarly dependent on coastwise shipping, and in the past this has suffered very heavily from unexpected northerly and northwesterly gales. The worst gales, moreover, come from a "blind corner" from which no weather reports are available. Jan Mayen fills that spot, and its importance has just been recognized by Norwegian meteorologists. Professor Bjerknes's (Director of the Bergen Meteorological Bureau) knowledge of the scientific and practical possibilities of a wireless station on Jan Mayen had to be supplemented, however, by Engineer Ekerold's enthusiasm and energy before the present station was set going. Ekerold put forward his plans in February, and after an interval of months was finally able to get a grant of about £2,000 from the Storthing. After that, the affair appeared simple. In reality it was the reverse. To stow the long tree trunks destined to be wireless masts in the two small ships was in itself a problem not easy to solve. Both ships left Aalesund heavily overburdened with deck cargoes. The next difficulty was to land the gear in the heavy surf. This difficulty, too, was overcome and the heavy material carried to the chosen site—a small plateau of volcanic sand, but frozen firm as iron at a depth of 2 feet. Work started on August 8. On September 17 the erecting party was able to leave for Norway in the *Isfuglen*, the engine at the station by then being already in running order and both masts (150 feet high) erected. It was possible to speak Norway with a single mast; with both it was a very simple proposition. Weather reports began at once and continued till September 24. On that day, however, a fierce gale raged all up and down the Norwegian coast; no further wireless messages came through, for in Jan Mayen, owing to faulty couplings, both masts collapsed in the gale. On October 19, however, Ekerold spoke Norway once more; he and his four companions had succeeded in putting shorter masts from the remains of the collapsed originals. The station, therefore, is now at last in running order, and messages are being received daily. It remains for the Norwegian weather bureau to gather and profit by the fruits of Ekerold's painstaking efforts.

ERRONEOUS REPORT OF EXCESSIVE RAIN.

According to a news report originating at Houston, Tex., 8.35 inches of rain was said to have fallen at Thornton, Tex., on July 19, within 40 minutes. On investigation by the local office of the Weather Bureau at Houston, Tex., it is found that the original report was seriously in error—the rainfall on the date in question being about an inch.

This note of explanation is published in the belief that it will prevent hydrographers from giving weight to the reported rainfall. It may be remembered that in the great rainstorm at Taylor, Tex., of September 9, 1921, which gave the greatest 24-hour rainfall of record in the United States, the 40-minute fall was but 8.02 inches.—*A. J. H.*

[1] Cf., J. M. Wordie: A summer visit to Jan Mayen Island. In *Nature* (London), **109**: 15-18.

ON DUST-RAISING WINDS.

By C. W. B. NORMAND.

[Excerpts from *Memoirs of the Indian Meteorological Department*, Vol. XXII, Part VII, 1921, pp. 575-581, bibliog.]

During the rainless, hot weather the whole land surface became parched and the alluvial soil, especially, developed a coating of fine dust [Samarrah, Mesopotamia, 1918]; in the areas of much traffic, the dust lay in places knee-deep. On days of light wind in August and September it was no uncommon occurrence to see three or four dust-devils of great height meandering with the breeze over this plain. These columns had quite sharp boundaries except at the top. They looked ridiculously high for their width, the base being generally of the order of 5 meters in diameter and the height of many at least 300 meters. * * * In their main essentials they did not differ from the similar dust columns of Egypt described half a century ago by Pictit, except that the Mesopotamian dust-devils must be described as having a cylindrical rather than a diverging conical shape. * * *

For the origin of dust-devils a highly unstable vertical distribution of temperature is necessary. The frequency of mirage in Mesopotamia shows that the density of the surface air layers often increases with height; in other words, the temperature lapse-rate near the ground must often exceed 3.4° C. in a hundred meters. * * * Some comparatively small impetus is all that is required therefore to set up a dust whirl on a calm day. * * *

The primary dust storm occurs principally between 4 p. m. and midnight in the months of March, April, May, and September. * * * With two exceptions the dust storms in spring were associated with thunderstorms and were undoubtedly due to the descending currents which are known to occur in front of thunderstorms. In an ordinary high wind the air may on some occasions become so charged with dust that objects can not be seen 30 yards away. * * *

In any physical explanation or mathematical examination of dust raising by wind, it is necessary to distinguish between two processes—(1) the raising of the dust from the ground and the consequent formation of a dusty surface layer of air, and (2) the ascent of dust from the surface to the higher layers. The first would seem to require, as a necessary condition, a relatively large transference of momentum to the surface dust from the air in contact with it. Hence, either (*a*) the surface layers must be moving exceptionally fast or (*b*) an unusually large amount of air strikes the ground at an angle, and on being deflected from its original direction transfers momentum to the surface air. In dust storms caused by high winds (*a*) is mainly operative; in dust columns and primary dust storms probably both (*a*) and (*b*) are of importance.

THE LOCAL DISTRIBUTION OF MONSOON RAINFALL.

By GILBERT T. WALKER.

[Abstract reprinted from *Memoirs of the Indian Meteorological Dept.*, Vol. XXIII, Part II, Calcutta, 1922.]

Experience of the past 13 years shows that the formula of 1908 for forecasting the whole monsoon rainfall of India affords a useful indication in years when the calculated departure is 1″ or over, which, on the average, form about half of the number of years. Investigation of the geographical distribution of rainfall leads to a subdivision of India into large homogeneous areas such as northwest India and the Peninsula, for which formulæ have been worked out, giving the total monsoon rainfall and that of August and September. The correlation coefficients range from 0.57 to 0.73. Similar formulæ have also been developed for Upper Burma, Mysore, and Malabar.

THE CALCULATION OF THE DEGREE OF CONTINENTALITY.[1]

By LADISLAS GORCZYŃSKI.

[Abstracted from *Geografiska Annaler*, 1920, H. 4, pp. 324-331.]

The degree of continentality of a given station may be computed by means of the formula

$$k = 1.7\ (A - 12\ \sin\phi)/\sin\phi$$
$$= (1.7\ A/\sin\phi) - 20.4$$

in which k is the thermal degree of continentality in per cent, A the amplitude of the mean annual temperature fluctuation and ϕ the latitude. The expression $A = 12 \sin \phi$ is found to be in good accord with observations over the oceans. The constant, 1.7, is derived from the assumption that Werchojansk, in eastern Siberia, is representative of 100 per cent continentality. The amplitude of the annual temperature variation is 65.9° C., and the latitude is 67° 33′ N.

Upon the basis of this formula, the author presents the geographical distribution of continentality, of which three degrees are distinguished:

(1) Transitional maritime, in which $k = 0$ to 33 per cent.
(2) Continental, in which $k = 34$ to 66 per cent.
(3) Extreme continental, in which $k = 67$ to 100 per cent.

One advantage of discussing continentality from the point of view of this formula, as opposed to the direct use of the amplitude of the annual variation of temperature, is shown by an illustration. Considering only amplitude of temperature variation, the Sahara Desert would fall in the same class as western Europe; whereas, computing continentality from this equation, the Sahara lies in groups (2) and (3) above, while western Europe lies in (1).

The values thus calculated show resemblances both to the "isocontinentals" of Zenker and the "equidistants" of Rohrbach, but possess certain advantages over these earlier attempts at discussing continentality.

The mean values of k (per cent) for the several continents are:

Europe	30 (max. 50, Oural).
Asia	58 (max. 100, Werchojansk).
Africa	36 (max. 75, Sahara).
North America with Greenland	44 (max. 70, $\phi = 66°$ N.).
South America	18 (max. 31, $\phi = 30°$ S.).
Australia	32 (max. 55, interior).
Artic Zone	40 (North Pole, 48).
Antarctic Zone	20 (South Pole, 26).

For the Northern Hemisphere (continents and oceans) the value is 20 per cent; for the Southern Hemisphere, 3 per cent.

A comparison of the relation $A = 12 \sin \phi$ with observed values over extensive ocean areas shows computed values in close agreement with observation. In the Southern Hemisphere, $A = 9 \sin \phi$ seems to give better agreement. This, of course, would lead to a somewhat different value of k, but a series of comparisons demonstrates that the differences would not exceed 3 per cent, which is considered sufficiently small.

The author presents world maps of the distribution of continentality as computed by this formula and of the distribution of amplitude of annual temperature variation.—*C. L. M.*

[1] *Sur le calcul du degré du continentalisme et son application dans la climatologie.*

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C. F. TALMAN, Meteorologist in Charge of Library.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY, 1922.

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**:225.

From Table 1 it is seen that direct solar radiation intensities averaged slightly above the normal for July at Madison, slightly below at Lincoln, and very close to normal at Washington.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged below the July normal at Washington. At Madison it averaged above the normal during the first and third weeks, and below the normal during the second and fourth weeks.

Skylight polarization measurements made on seven days at Washington give a mean of 50 per cent with a maximum of 61 per cent on the 29th. These are close to average values for July at Washington. At Madison, measurements made on five days give a mean of 70 per cent with a maximum of 72 per cent on the 3d and 13th. The mean is above the average polarization for July at Madison.

TABLE 1.—*Solar radiation intensities during July, 1922.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance. 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
July 6	14.10	.....	0.69	0.78	1.00	.....	.....	.....	.....	.....	9.83
12	19.89	0.48	0.61	0.75	0.94	1.21	0.96	0.76	0.57	.....	19.89
17	18.59	0.50	0.59	0.75	0.93	.....	.....	.....	.....	.....	19.89
18	17.96	.....	.....	.....	1.02	1.32	.....	.....	.....	.....	18.59
21	13.13	.....	.....	0.67	0.86	1.05	.....	.....	.....	.....	12.24
28	19.23	.....	.....	.....	.....	1.00	.....	.....	.....	.....	17.96
29	12.24	0.69	0.80	0.93	1.05	1.23	.....	.....	.....	.....	12.24
31	14.10	.....	.....	.....	1.01	1.10	.....	.....	.....	.....	12.68
Means	.....	**0.56**	**0.67**	**0.78**	**0.97**	**1.15**	**(0.96)**	**(0.76)**	**(0.57)**	.....	.....
Departures	.....	**−0.02**	**−0.02**	**−0.04**	**+0.06**	**+0.04**	**±0.00**	**±0.00**	**−0.08**	.....	.....

TABLE 1.—*Solar radiation intensities during July, 1922*—Continued.

Madison, Wis.

Date.	Sun's zenith distance. 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
July 1	16.79	.....	.....	0.71	.....	.....	.....	.....	.....	.....	16.20
3	8.18	.....	.....	.....	1.26	1.45	.....	.....	.....	.....	8.48
8	11.38	.....	.....	.....	1.21	.....	.....	.....	.....	.....	9.47
13	14.10	.....	.....	1.02	1.19	1.39	.....	.....	.....	.....	15.65
18	10.59	.....	.....	.....	1.20	1.39	.....	.....	.....	.....	13.61
19	11.38	.....	.....	1.03	1.19	1.37	.....	.....	.....	.....	12.68
Means	.....	.....	.....	**0.92**	**1.21**	**1.40**	.....	.....	.....	.....	.....
Departures	.....	.....	.....	**+0.03**	**+0.18**	**+0.14**	.....	.....	.....	.....	.....

Lincoln, Nebr.

July 4	9.83	.....	.....	0.82	1.01	1.17	.....	.....	.....	.....	9.47
5	10.97	.....	0.65	0.77	0.96	.....	.....	.....	.....	.....	14.60
7	11.38	.....	1.01	1.10	1.25	1.42	.....	.....	.....	.....	11.38
8	11.38	.....	.....	0.95	.....	.....	.....	.....	.....	.....	13.61
13	11.81	.....	0.76	0.89	1.10	.....	1.01	0.78	0.61	.....	11.38
15	16.20	.....	.....	0.80	1.00	1.26	.....	.....	.....	.....	16.79
18	11.81	.....	0.81	0.91	1.08	.....	1.05	0.88	0.74	.....	10.59
19	11.38	.....	.....	0.79	1.00	1.22	.....	.....	.....	.....	13.61
25	13.61	.....	.....	.....	.....	.....	1.02	0.84	0.73	.....	18.59
26	17.96	.....	.....	0.89	1.07	1.27	1.07	0.89	0.74	.....	17.37
27	14.60	.....	.....	.....	.....	1.34	1.07	0.87	0.72	.....	14.60
28	15.65	.....	.....	.....	.....	1.08	0.89	.....	.....	.....	17.96
31	13.61	.....	.....	0.92	1.05	.....	.....	.....	.....	.....	25.96
Means	.....	.....	.....	**0.81**	**0.88**	**1.06**	**1.25**	**1.02**	**0.85**	**0.71**	.....
Departures	.....	.....	.....	**+0.1**	**−0.02**	**−0.02**	**−0.08**	**−0.05**	**−0.04**	**−0.04**	.....

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation. Washington.	Madison.	Lincoln.	Average daily departure for the week. Washington.	Madison.	Lincoln.	Excess or deficiency since first of year. Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 2	452	561	.....	−56	+23	.....	−3094	−1541	.....
9	477	459	.....	−21	−72	.....	−3243	−2048	.....
16	423	522	.....	−64	+ 5	.....	−3690	−2016	.....
23	453	419	.....	−24	−77	.....	−3861	−2556	.....

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington.]

NOTE.—Owing to delay in the mails the data from South America will be included in the August issue of the REVIEW.—EDITOR.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was somewhat higher than usual at land stations on the Atlantic coasts of Canada and the United States, as well as in the Bermudas and Azores. It was nearly normal on the north coast of Scotland and slightly below in the southern part of England.

From reports received the number of days with fog was apparently not far from the normal.

July is ordinarily the quietest month of the year over the North Atlantic. While during the month under discussion the number of days with winds of gale force was somewhat greater than usual off the coast of Great Britain, for the remainder of the ocean it was about normal.

From the 1st to 4th moderate weather was the rule over the ocean, except for a disturbance of limited extent in the vicinity of the British Isles, the storm area extending as far west as the 23d meridian. Storm logs follow:

American S. S. *Bremerton:*

Gale began on the 1st; wind SW. Lowest barometer 29.18 inches at 8 a. m. on the 1st; wind SW., in latitude 53° 37′ N., longitude 19° 02′ W. End on the 2d; wind NW. Highest force of wind 8, WNW.; shifts SW.–W.

Dutch S. S. *Alkmaar:*

Gale began on the 3d; wind WSW. Lowest barometer 29.72 inches at 4 a. m. on the 4th, wind W., in latitude 49° 38′ N., longitude 11° 32′ W. End on the 4th; wind W. Highest force of wind 8; shifts WSW.–SSW.–S.–WSW.–W.

American S. S. *Bremerton:*

Gale began on the 3d; wind W. Lowest barometer 29.63 inches at 8 a. m. on the 3d, wind W., in latitude 50° 47′ N., longitude 24° 15′ W. End on the 3d; wind NW. Highest force of wind 8; shift N.–NW.

On the 3d the American S. S. *Gen. W. C. Gorgas* encountered a moderate northeasterly gale in the Carribbean Sea, while other vessels in the vicinity experienced moderate weather. Report follows:

July 3, a. m., weather partly cloudy, moderate gale from northeast; heavy head sea, barometer 30 inches; p. m., similar weather. Greenwich mean noon position, latitude 14° 48′ N., longitude 75° 48′ W.

On the 5th there was a disturbance central near latitude 47° N., longitude 15° W. Storm log:

British S. S. *City of Weatherford:*

Gale began at 8 a. m. on the 5th; wind W., 6. Lowest barometer 29.34 inches at noon on the 5th, wind W., 8, in latitude 46° 09′ N., longitude 17° 49′ W. End at 10 p. m. on the 5th; wind NW. Highest force of wind 8, NW.; shifts W.–NW.

This LOW moved rapidly eastward, and during the period from the 6th to the 9th, as shown on Charts VIII to XI, inclusive, a very severe disturbance, limited in area and intermittent in character, swept the southern coast of the British Isles. Storm logs:

American S. S. *Carplaka:*

Gale began on the 6th; wind S. Lowest barometer 29.11 inches at 8 a. m. on the 6th, wind S., 8, in latitude 50° 58′ N., longitude 1° 08′ E. End on the 9th; wind NW. Highest force of wind 12; steady from S.

American S. S. *Connes Peak:*

Gale began on the 5th; wind SE. Lowest barometer 29.03 inches at midnight on the 6th, wind SW., 9, in latitude 50° 10′ N., longitude 2° 30′ W. End on the 9th; wind W. Highest force of wind 10, NNW.; shifts SE.–E.–SW.–NW.–WNW.

At the time of Greenwich mean noon observation on the 7th there seemed to be a lull in the storm, as all reports received to date indicate moderate weather. At the time of observation on the 8th, however, the wind was blowing with hurricane force, causing considerable damage not only to shipping but also on shore.

While the storm area at Greenwich mean noon on the 8th did not extend west of the 15th meridian, vessels near mid-ocean reported gales later in the day, as shown by the following storm logs:

American S. S. *Noccalula:*

Gale began on the 8th; wind SW. Lowest barometer 30.04 inches at 8 p. m. on the 8th, wind SW., in latitude 47° 16′ N., longitude 28° 47′ W. End at 11 p. m. on the 8th; wind SW. Highest force of wind 8, SW.; shifts SW.–WNW.

British S. S. *Lackawanna:*

Gale began on the 7th; wind S. Lowest barometer 29.75 inches at 8 a. m. on the 8th, wind SSW., in latitude 50° 40′ N., longitude 36° 10′ W. End on the 9th; wind NW. Highest force of wind 8; shifts SSW.–SW.–WNW., slowly.

By the 9th the force and extent of this disturbance had diminished considerably, although a moderate westerly gale still occurred in the vicinity of the English Channel.

The intensity of this storm was so great that the French liner *Lafayette* was obliged to return to port on the morning of the 9th, after encountering such violent weather in the English Channel that the ship was flooded, the damage being so heavy that extensive repairs will be necessary. Storm logs follow:

American S. S. *President Polk:*

Gale began on the 8th; wind S. Lowest barometer 29.40 inches at 1 a. m. on the 8th, wind S., 5, in latitude 50° 01′ N., longitude 5° 10′ W. End on the 9th; wind NW. Highest force of wind 9, WSW.; shifts S.–SSW.–WSW.–WNW.–NW.

American S. S. *Janelew:*

Gale began on the 9th; wind W. Lowest barometer 29.64 inches at 12:30 a. m. on the 9th, wind W., 7, in latitude 51° 30′ N., longitude 3° E. End on the 10th. Highest force of wind 8; steady from W.

From the 10th to the 16th moderate weather was the rule over the entire ocean, with comparatively high pressure and slight gradients.

On the 17th and 18th there was a disturbance over a limited area in the middle western section of the steamer lanes, as shown by following storm logs:

British S. S. *Valemore:*

Gale began on the 17th; wind SSE. Lowest barometer 29.60 inches at 4 p. m. on the 17th, wind SW., 8, in latitude 44° N., longitude 51° W. End on the 17th; wind NW. Highest force of wind 8, SW.; shifts SW.–NW.

American S. S. *Anacortes:*

Gale began on the 17th; wind NNW. Lowest barometer 29.88 inches at 6 a. m. on the 18th, wind NNW., 8, in latitude 41° 42′ N., longitude 45° 30′ W. End on the 18th; wind NNW. Highest force of wind 8; shifts W.–WNW.

On the 20th there was a fairly well-developed LOW central near Hatteras that moved slowly northeastward, as by the 21st it was in the vicinity of Nantucket. Storm logs:

British S. S. *Parima:*

Gale began on the 20th; wind SW. Lowest barometer 29.91 inches at 6 p. m. on the 20th, wind SW., 8, in latitude 36° 33′ N., longitude 72° W. End on the 20th. Highest force of wind 8; shifts SW.–W.–WNW.

American S. S. *America:*

Gale began on the 21st; wind SW. Lowest barometer 29.80 inches at 3 a. m. on the 21st, in latitude 40° 50′ N., longitude 66° 35′ W. End on the 21st; wind NW. Highest force of wind 9; shifts SW.–NW.

From the 22d to the 24th another period of atmospheric inactivity ensued, with light to moderate winds over the entire ocean.

On the 25th a LOW of slight intensity and extent developed near latitude 55° N., longitude 30 W.; this moved but little during the next 24 hours, the wind increasing slightly in velocity. Storm logs follow:

British S. S. *Siamese Prince:*

Gale began on the 25th; wind SSW. Lowest barometer 29.35 inches at 6 p. m. on the 25th, wind SSW., 7, in latitude 55° 18′ N., longitude 22° W. End on the 26th; wind W. Highest force of wind 9, W.; shifts W. by N.–W.

British S. S. *Kenbane Head:*

Gale began on the 25th; wind WNW. Lowest barometer 28.84 inches at 5 p. m. on the 25th, wind W., 8, in latitude 56° 15′ N., longitude 30° 30′ W. End on the 27th; wind SW. Highest force of wind 10, W.; shifts WNW.–W.

On the 26th the American S. S. *Tivives* encountered northeasterly winds of gale force near the coast of Colombia, as shown by the following report:

Left Santa Marta, Colombia, at 10 p. m. on the 26th. Very heavy sea and wind of gale force. P. M. of the 26th wind and sea moderating. Position, Greenwich mean noon of the 26th, latitude 10° 46′ N., longitude 76° W. Barometer 29.88 inches. Wind ENE., 7.

On the 30th and 31st there was a LOW in the vicinity of Nova Scotia and Newfoundland, with light to moderate winds in the southerly quadrants, no reports having been received up to date from vessels north of the 50th parallel and west of the 50th meridian.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Five typhoons occurred in the Far East in July—one from the 3d to the 9th, another from the 9th to the 13th, a third from the 23d to the 25th, a fourth from the 26th to 29th, a fifth from the 25th to 31st. Inasmuch as the last one of these storms continued into August, causing the destruction of Swatow on the 2d, its history more properly belongs to that month. Ordinarily some three or four typhoons occur in July.

The first of the typhoons appeared to the eastward of northern Luzon, near latitude 18° N., longitude, 126° E., on July 3. It moved almost due northward, the center passing near Okinawa Island on the 5th and traversing the Eastern Sea on the 6th and morning of the 7th. During the afternoon of the 7th it traveled along the eastern coast of Chosen and thence, on the 8th and 9th, into northern Manchuria. On the 7th this typhoon caused a heavy rainstorm in western Japan.

The second typhoon was a small one which apparently formed to the westward of the Ladrones on the 18th. It moved in a westerly direction and passed over the Philippines on the 19th. Thus far little is known of its history.

Details of the other typhoons of the month will appear in the August REVIEW.

Conditions over the eastern part of the Pacific were characterized by high pressure over the Aleutian area and more than the usual amount of fog along the northern steamer routes. In the region of the Aleutian Islands the highest pressure of the year ordinarily occurs in July. For the years 1912–1920 the average of the p. m. barometer readings at Dutch Harbor is 30.02 inches, as compared with 29.54 inches in December, the month of lowest pressure, and a yearly average of 29.76. The average for the present July was 30.15 inches. The highest reading, 30.56, occurred on the 11th and the lowest, 29.66, on the 7th.

At Midway Island, on the contrary, pressure was below normal by some 0.06 inch, the average of the p. m. barometer readings being 30.04. The highest reading recorded was 30.16 inches on the 22d, the lowest 29.86 on the 17th. At Honolulu pressure was above normal by somewhat more than 0.01 inch. The highest reading was 30.11 on the 26th, the lowest 29.92 on the 13th.

Aside from the influence exerted by the typhoons in waters of the Far East the month was characteristically quiet. Only on a few occasions did the wind reach the force of even a moderate gale. Of these perhaps the most interesting, on account of the region in which encountered, was the gale experienced on July 31 by the American S. S. *Pacific*, Capt. William Mepham, during a voyage from Honolulu to Panama. C. A. Martell, chief officer and observer, has submitted the following report:

About 4:30 p. m. (L. M. T.) of the 31st, when in latitude 15° 05′ N., longitude 119° 01′ W., the eastern horizon began packing up with A. St. and Nb. clouds, wind ENE., force 4, barometer 29.81 (corrected). At 5 p. m. clouds increased to 6 with "scud" flying violently from E., wind increasing to 5–6, shifting to E. by N., barometer dropping. At 5:30 sky overcast with A. St. and Nb., wind shifting from E. by N. to E., to E. by S., to ESE. in a period of 10 minutes, force 7, violent and heavy rain. Barometer now reading 29.74 (lowest point), very rough, confused sea rising. At 6 p. m. wind dropped to force 2 and shifted to SE., clouds the same. At 6:30 clouds clearing, barometer rising to 29.86, wind SE. At 6:45 clouds 10 Nb., heavy rain, barometer 29.84, wind SE., 2. At 7:15 barometer 29.93, passing rains, wind SE., 3, clouds Nb. 10.

The weekly weather reports of the Imperial Marine Observatory, Kobe, show that anticyclonic conditions prevailed over the ocean area immediately to the eastward of Japan until the 19th, the date of the latest report received. From the 1st to the 19th, with the exception of the typhoon of the first week, but three cyclones affecting the weather of Japan were charted, all continental in type. The first of these appeared in Siberia on the 3d, the second in Mongolia on the 12th, the third in northern China on the 17th. All three moved northeastwardly in the direction of Kamchatka and their influence was only slightly felt over the western portion of the steamer routes.

Several vessels on the northern steamer routes reported an unusual amount of fog. The British S. S. *Empress of Asia* had continuous thick fog for 34 hours on the 25th and 26th. G. M. N. positions on those days, respectively, 46° 39′ N., 169° 03′ E. and 48° 47′ N., 179° 56′ E.

The American S. S. *Alloway* reports as follows:

Dense fog, continuous from 9 p. m. July 2 to 3:14 a. m. July 4.
July 5 and 6, passing fog banks, lasting 20 minutes each.
July 7 and 11, continuous fog. Part of time dense, heavy fog; small portion of time passing banks.

G. M. N. positions of the *Alloway* were as follows: 2d, 41° 27′ N., 151° 41′ E.; 4th, 45° 39′ N., 161° 40′ E.; 6th, 48° 04′ N., 169° 28′ E.; 11th, 48° 59′ N., 164° 38′ W.

The British S. S. *Waitemata* reports that from noon of the 2d to 9:30 a. m. of the 10th fog prevailed nearly all the time. When it lifted at times visibility was very poor and mist was always present. G. M. N. positions: 2d, 43° 10′ N., 157° 49′ E.; 10th, 50° 22′ N., 157° 53′ W.

SOUTH PACIFIC OCEAN.

The British S. S. *Waiduna*, Capt. A. T. Norton, Observer H. A. Brockett, Wellington for Tahiti and San Francisco, experienced heavy weather on July 6 to 8, the wind reaching the force of a strong gale, accompanied by high seas. The lowest barometer, 29.64 (corrected), occurred at 4 a. m. of the 6th, in 35° S., 174° W., shifts E. to ESE.

A LOOCHOOS AND JAPAN TYPHOON, JUNE 7 TO 11, 1922.

By Rev. José Coronas, S. J.

[Weather Bureau, Manila, P. I.]

The only typhoon worth mentioning that visited the Far East during the last month of June was that which formed on the 7th over the northeastern part of the China Sea in about 116° or 117° longitude E. and 18° or 19° latitude N. It formed after several days of a low-pressure area extending from the China Sea to the Pacific across the Balintang Channel and northern Luzon.

After the typhoon was formed it took a northeasterly direction, passing between the Batanes and Formosa in the morning of the 8th and traversing the Loochoos on the 9th. The barometric minima as observed at Ishigakihima and Naha were, respectively, 741.1 millimeters (29.18 inches) at 3 a. m. of the 5th and 735.8 millimeters (28.97 inches) at 3 p. m. of the same day.

The approximate positions of the typhoon at 6 a. m. of the 9th and 10th, respectively, were 125° longitude E., 24° latitude N.; and 130° longitude E., 27° or 28° latitude N.

The weather maps of Tokio show the center over, or close to, the southeastern coast of Japan, south and east of Tokio, during the night of June 10 to 11.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—Unusually heavy gales for the season of the year have occurred over England during the early part of July, especially during the night of July 5–6, and the tempestuous winds were accompanied by torrential rains. On the southeast coast of England the wind attained the velocity of about 60 miles an hour, and at Kew Observatory the velocity registered 53 miles an hour. London experienced considerable interruption to telephone communication, and in the open country much damage was done to the fruit crops. A renewal of the stormy conditions occurred on July 8–9.—*Nature (London), July 15, 1922.*

France.—Clermont Ferrand, July 17.—Unseasonable, cold weather was felt to-day throughout the Auvergne region, the thermometer registering 36° F. Snow was falling on the mountains.—*Springfield (Mass.) Republican, July 18, 1922.*

Switzerland.—Geneva, July 18.—Mountain climbing is temporarily impossible in Switzerland. Inhabitants are experiencing the coldest July in many years. Heavy snowfalls occurred yesterday at an altitude of 6,000 feet, which is less than halfway up Mont Blanc. Heavy rains fell in the lower altitudes, with cloudbursts in some localities. The Rhine, which reached a low record last year, is now high and threatening floods.—*Binghamton (N. Y.) Morning Sun, July 22, 1922.*

India.—The Indian monsoon has been slightly stronger than usual and gives good promise for agricultural operations. Excellent rains have fallen over the greater part of the country and there are only a few regions, notably Kathiawar, Cutch, and parts of the Punjab, where further rainfall is necessary. In some areas of the Deccan there has been about 1,000 millimeters of rain and the sun has scarcely been seen for weeks.—*Meteorological Magazine August, 1922, p. 197.*

Japan.—Tokio, July 21.—The rice crop of Japan has already been severely threatened, owing to a prolonged drought. * * * This shortage of water applies to virtually the whole country and Korea, and in some places there is even a shortage of drinking water.—*Binghamton Morning Sun, July 22, 1922.*

Australia.—At the beginning of the month the temperature at Melbourne fell as low as 32° F. and snow occurred as far to the northeast as Albury, on the River Murray. A message from Melbourne, dated July 31, stated that the highest flood waters experienced in 20 years were slowly moving down the Murrumbidgee River and had gradually inundated the town of Wagga Wagga.—*Meteorological Magazine, August, 1922, p. 197.*

Brazil.—A stationary depression over the Province of Entre Rios, in the Argentine, at the end of June and beginning of July gave very heavy rains accompanied by gales. * * *

The cane and cotton crops were still feeling the consequences of last month's heavy rain, and wheat was slightly affected by the relatively high temperature.—*Meteorological Magazine, August, 1922, p. 202.*

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

By A. J. Henry.

The outstanding feature of the month seems to have been the high monthly mean pressure that prevailed on both the Atlantic and Pacific coasts and in the northern Plain States. Pressure over the western North Atlantic, as at Bermuda, was exceptionally high, the mean for the month being 30.28 inches, the highest July mean recorded in 27 years. The temperature was very close to normal in all parts of the country, but the rainfall was irregularly distributed, as may be seen from the small inset chart on Chart IV—Total Precipitation.

Anticyclones were quite frequent in the upper Missouri Valley, but a large percentage did not advance out of that region; on the other hand, those which reached the Lake region continued to advance to the Canadian Maritime Provinces, and thence over the western portion of the Atlantic, reinforcing the semipermanent anticyclone over those waters.

CYCLONES AND ANTICYCLONES.

By W. P. Day, Meteorologist.

There were few typical cyclonic disturbances. These for the most part were temporary developments along the axis of the larger troughs of low pressure which carried completely across the continent. Six of these troughs completely traversed the breadth of the United States during the month, averaging six days in crossing. An equal number of high-pressure crests persisted until they coalesced with the North Atlantic anticyclone. Offshoots from the North Pacific anticyclone moved inland, but just as they were about to disintegrate over the Eastern Slope, the high pressure was reinforced on

the north by an Alberta, or farther east by a Hudson Bay anticyclone. The pressure-wave crest usually succeeded in crossing the continent by this system of relays. The direct result of this succession of high and low pressure areas was a frequent alternation in temperature over northern and central districts.

Cyclones.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total
July, 1922	3.0	1.0	.....	.....	1.0	.....	2.0	.....	2.0	9.0
Average number 1892–1912, inclusive	4.8	0.7	0.3	0.5	0.9	0.2	0.1	0.1	1.0	8.6

Anticyclones.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
July, 1922	3.0	.....	4.0	2.0	3.0	12.0
Average number 1892–1912, inclusive	1.3	0.3	3.0	1.2	0.8	6.6

FREE-AIR CONDITIONS.

By L. T. SAMUELS, Meteorologist.

Mean free-air temperatures for the month (Table 1) showed a general tendency, with increase in elevation, to approach average conditions. At the surface and lower levels, however, all the departures were negative, and closely conformed in amount with those shown in Climatological Chart III. It will be noted that at Drexel and Royal Center, the regions having the largest departures, these were all negative from the surface to the highest level, while at the other four stations the sign was reversed and positive departures were found in the higher levels. In general, where the negative departures at the surface were smallest the positive departures were found nearer the surface accordingly.

The mean relative humidities were in general inversely proportional to the temperatures as regards departures from the average, a condition to be expected. A prolonged dry spell occurred in the upper levels at Groesbeck from the 9th to the 12th, inclusive, when a rather strong low-pressure area central to the north of Groesbeck caused steady and deep southwesterly winds with resulting low relative humidity. Values from 14 to 20 per cent were reported from the 2,000-meter to 3,000-meter levels during this entire period, whereas the average values for these levels are 52 and 54 per cent, respectively.

Vapor pressure departures conformed in general to the temperature departures with the greatest negative values occurring at Drexel, where it will be noted negative temperature departures were largest.

In Table 2 are given the resultant winds for the month, and it will be noted that these correspond quite closely to the average values. At Drexel, where the largest negative temperature departures occurred, will also be found a much smaller southerly component in the resultant directions than normally. Only a few observations showed wind velocities exceeding 30 meters per second, and these are given in the following table:

Stations.	Date.	Direction.	Velocity.	Altitude.
			m. p. s.	*m.*
Burlington, Vt.	22	WNW	30	6,800
Drexel, Nebr.	13	WNW	30	10,900
Ellendale, N. Dak.	7	NW	30	9,300
Do.	12	NW	34	9,100
Do.	29	WSW	40	9,700
Ellington Field, Tex.	21	SW	44	6,900
Royal Center, Ind.	13	SW	30	10,300
Do.	28	NW	30	6,000
Scott Field, Ill.	23	WNW	30	2,700

All of these were pilot-balloon observations. The kite flight at Royal Center on the morning of the 7th indicated high winds aloft, but the kites were beaten down at 2,000 meters, where the velocity was 29 meters per second. Southwest storm warnings were displayed on the Lower Lakes at 10 a. m. that morning, and because of the quick movement of the storm the warnings were ordered down the following evening.

During the late afternoon and night of the 13th an unusually severe electrical storm occurred at Washington, D. C., the rainfall totaling 3.37 inches, of which 2.79 inches fell within one hour. Examination of the free-air observations in connection with this storm reveals the interesting and significant fact that differently directed air currents prevailed over this section of the country at and previous to the time of the storm. The surface weather map showed this region to be under the influence of a low-pressure trough, lying between two adjacent high-pressure areas, a condition suitable for over and under running currents of air.

Pilot-balloon observations on the afternoon of the 13th at Bolling Field and Washington, D. C., showed northerly winds at the surface, changing through the west to southerly at about 1,500 meters above. Stations to the south of those named above, however, viz, Camp Bragg, N. C.; Langley Field, Va.; and Lee Hall, Va., had southerly winds extending from the surface to the upper levels. Dahlgren, Va., situated between Washington, D. C., and Langley Field, Va., reported northerly winds from the surface to 1,500 meters—the highest level reached. The movement of both the lower and upper clouds at this station, however, was from the south or southwest. Thus it is evident that a southerly current was overrunning a northerly one, the former extending obliquely from the surface at some place south of Dahlgren and north of Langley Field. The 3 p. m. pilot-balloon observation at Washington, D. C., showed this southerly current to be about 1,500 meters above the surface. At Aberdeen, Md., to the north of Washington, this current was not observed, although the balloon was followed to an altitude of 3,000 meters. Furthermore, the Ci.-St. clouds at this observation were reported as moving from the NW.

This condition, i. e., a cool northerly current underrunning one of higher temperature, and the latter probably being very humid, undoubtedly contributed largely toward the production of excessive condensation. It is very probable that in view of the apparent steepness of the slope of this southerly current, the opposite northerly one cut and overran the one from the south, thereby producing favorable conditions for strong convection in these higher levels and terminating in a thunderstorm. Such an unstable condition would be accelerated because of the latent heat liberated by the condensation taking place in the moist layer of air from the south.

On the morning of the 12th the weather map showed the surface isobars to be widely separated in the eastern section of the country and conditions were favorable for high pilot-balloon soundings. The balloon at Washington, D. C., on the morning of this date was observed for 114 minutes and reached an altitude of 20,000 meters. The record appears trustworthy and has been accepted as substantially correct. The wind direction was southerly from the surface to 10,000 meters, above which it was easterly to the highest level observed. The velocity of the southerly wind averaged only 3 or 4 meters per second, but as soon as the upper easterly was encountered the wind speed increased accordingly to about 10 meters per second, falling off again to nearly calm at 14,000 meters and increasing again to 16 meters per second at 19,000 meters. This upper easterly wind was also reached on the same morning at Aberdeen, Md.

On the mornings of the 28th and 29th altitudes of 28,000 and 17,000 meters, respectively, were reached at Broken Arrow, Okla. Both were made with a single theodolite. There was a nearly calm condition of the atmosphere between 6 kilometers and 12 kilometers on the 28th and between 3 kilometers and 14 kilometers on the 29th. On the 28th the velocity increased gradually above 12 kilometers, but from 23 kilometers the record is very likely in error and the balloon probably became leaky, causing an apparent sharp increase in velocity to the highest level. The wind direction above 12 kilometers was northerly. A double-theodolite observation would have been very interesting in connection with such a long run, so that more credence might be placed in the respective altitudes, and therefore another observation was begun with two theodolites, but this was ended when the balloon burst at 14 kilometers. To this height the ascensional rate of the balloon was found to correspond beautifully with the assumed rate in the single-theodolite observation. On the 29th the direction above 14 kilometers was northerly.

Easterly movement of the atmosphere above 10,000 meters was observed as follows:

Station.	Dates.
Aberdeen, Md	12, 13.
Broken Arrow, Okla	15, 24, 25, 28, 29.
Due West, S. C	11, 25.
Ellendale, N. Dak	11.
Groesbeck, Tex	5, 10, 17, 20, 24, 25, 27, 30, 31.
Key West, Fla	26.
Rockwell Field, Calif	12.
San Francisco, Calif	10.
Washington, D. C	12.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during July, 1922.*

TEMPERATURE (°C.).

Altitude, m. s. l. (m.)	Broken Arrow, Okla. (233m.)		Drexel, Nebr. (396m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)	
	Mean.	Departure from average.	Mean.	Departure from average.	Mean.	Departure from average.	Mean.	Departure from average.	Mean.	Departure from average.	Mean.	Departure from average.
Surface	25.9	−1.3	21.9	−3.0	27.0	−0.3	20.2	−0.9	26.6	−0.2	24.2	−1.5
250	25.8	−1.3	.....	.....	26.7	−0.3	.....	.....	25.7	−0.2	23.9	−1.6
500	24.6	−0.6	21.0	−3.3	24.9	+0.3	20.1	−0.7	23.9	−0.1	20.7	−2.3
750	23.4	−0.2	19.7	−3.3	23.2	+0.5	19.2	−0.3	23.0	+0.2	18.8	−2.2
1,000	22.4	+0.3	18.6	−3.0	21.4	+0.5	17.8	−0.5	21.8	+0.2	17.2	−2.1
1,250	21.0	+0.5	17.4	−2.8	19.7	+0.4	16.6	−0.6	20.7	+0.4	15.7	−1.9
1,500	19.4	+0.5	16.3	−2.4	18.1	+0.4	15.2	−0.9	19.4	+0.5	14.1	−1.9
2,000	16.7	+1.0	13.9	−1.7	14.5	+0.1	12.5	−1.0	17.1	+0.9	11.5	−1.7
2,500	14.0	+1.5	10.9	−1.4	10.9	−0.2	9.8	−0.8	14.4	+1.1	9.1	−1.5
3,000	10.7	+1.4	8.1	−0.8	7.6	−0.4	7.4	−0.2	11.5	+1.1	6.3	−1.4
3,500	8.1	+1.6	5.0	−0.4	4.4	−0.4	5.1	+0.6	8.5	+1.2	3.6	−1.1
4,000	4.7	+1.3	1.9	−0.3	1.4	−0.4	3.0	+0.9	4.9	+0.9	0.8	−1.4
4,500	.....	.....	−1.7	−0.7	−1.8	−0.4	1.4	+1.3	.....	.....	.....	.....
5,000	.....	.....	.....	.....	−5.0	−0.4	.....	.....	.....	.....	.....	.....

RELATIVE HUMIDITY (%).

Surface	75	+6	71	+6	71	+1	70	0	75	−1	63	+3
250	74	+5	.....	.....	71	+1	.....	.....	76	0	64	+4
500	66	0	70	+6	70	−1	68	−1	76	0	69	+7
750	61	−4	66	+5	71	−2	64	+1	70	−1	70	+6
1,000	59	−6	64	+4	74	−1	64	+3	67	0	70	+5
1,250	59	−6	62	+3	75	−1	63	+4	62	−3	70	+5
1,500	59	−5	61	+3	74	−1	64	+8	59	−4	70	+5
2,000	54	−7	58	+2	76	+1	63	+10	52	−9	65	+4
2,500	49	−9	53	−1	78	+3	62	+11	53	−6	53	−1
3,000	47	−8	47	−6	76	+2	61	+11	54	−3	52	+2
3,500	35	−15	48	−5	71	+2	62	+10	54	−2	52	+5
4,000	33	−15	47	−4	63	+2	64	+11	67	+7	51	+10
4,500	.....	.....	65	+12	53	+2	69	+12	.....	.....	.....	.....
5,000	.....	.....	.....	.....	51	+2	.....	.....	.....	.....	.....	.....

VAPOR PRESSURE (*mb.*).

Surface	24.96	+0.44	18.64	−1.47	25.08	+0.27	16.49	−0.85	25.53	−0.94	18.62	−0.97
250	24.63	+0.39	.....	.....	24.71	+0.33	.....	.....	24.66	−0.68	18.42	−0.93
500	20.59	−0.47	17.53	−1.59	21.90	+0.29	15.99	−0.77	22.24	−0.44	16.46	−0.84
750	17.46	−1.26	15.32	−1.65	19.99	+0.07	14.21	−0.11	19.16	−0.46	14.84	−0.73
1,000	15.76	−1.21	13.90	−1.49	18.55	+0.11	12.94	+0.13	16.81	−0.40	13.47	−0.70
1,250	14.31	−1.01	12.51	−1.43	17.11	+0.18	11.68	+0.23	14.75	−0.61	12.18	−0.57
1,500	13.07	−0.59	11.33	−1.18	15.16	+0.17	10.80	+0.72	12.99	−0.80	10.94	−0.46
2,000	10.14	−0.58	9.23	−0.69	12.71	+0.34	9.13	+0.95	10.15	−1.17	8.36	−0.24
2,500	7.66	−0.65	7.13	−0.71	10.37	+0.40	7.78	+1.06	8.54	−0.65	5.47	−0.63
3,000	5.77	−0.50	5.13	−0.95	8.29	+0.27	6.65	+1.15	7.29	−0.25	4.38	−0.21
3,500	3.40	−1.21	4.30	−0.50	6.11	+0.27	6.04	+1.30	6.09	−0.07	3.97	+0.39
4,000	2.19	−1.17	3.37	−0.33	4.35	+0.27	5.44	+1.51	5.97	+0.72	3.63	+1.02
4,500	.....	.....	3.23	+0.19	3.17	+0.27	5.38	+1.59	.....	.....	.....	.....
5,000	.....	.....	.....	.....	2.46	+0.27	.....	.....	.....	.....	.....	.....

TABLE 2.—*Free-air resultant winds (m. p. s.) during July, 1922.*

Altitude, m. s. l. (m.)	Broken Arrow, Okla. (233m.)				Drexel, Nebr. (396m.)				Due West, S. C. (217m.)				Ellendale, N. Dak. (444m.)				Groesbeck, Tex. (141m.)				Royal Center, Ind. (225m.)			
	Mean.		Average.		Mean.		Average.		Mean.		Average.		Mean.		Average.		Mean.		Average.		Mean.		Average.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S.	3.6	S. 3° W.	3.3	S. 2° E.	1.7	S. 1° W.	2.2	S. 62° W.	2.7	S. 62° W.	2.4	N. 68° W.	1.5	S. 89° W.	0.2	S. 23° W.	3.9	S. 19° W.	3.4	S. 55° W.	2.9	S. 76° W.	1.6
250	S.	3.6	S. 4° W.	3.4	.....	.....	.....	.....	S. 62° W.	2.9	S. 62° W.	2.5	.....	.....	.....	.....	S. 29° W.	5.3	S. 23° W.	4.2	S. 53° W.	3.4	S. 77° W.	1.8
500	S. 5° W.	4.1	S. 13° W.	4.4	S.	2.5	S. 4° W.	3.0	S. 62° W.	4.1	S. 65° W.	3.1	N. 80° W.	1.3	S. 34° W.	0.4	S. 41° W.	7.7	S. 33° W.	6.1	S. 55° W.	6.5	S. 73° W.	3.0
750	S. 14° W.	4.3	S. 22° W.	4.8	S. 22° W.	3.3	S. 18° W.	4.1	S. 69° W.	4.3	S. 78° W.	3.4	S. 71° W.	2.1	S. 27° W.	1.1	S. 42° W.	7.7	S. 35° W.	6.2	S. 55° W.	8.5	S. 71° W.	4.1
1,000	S. 24° W.	4.2	S. 29° W.	4.7	S. 42° W.	3.5	S. 27° W.	4.5	S. 74° W.	4.5	S. 80° W.	3.9	S. 75° W.	2.5	S. 49° W.	1.7	S. 43° W.	7.4	S. 36° W.	5.8	S. 62° W.	8.5	S. 77° W.	4.6
1,250	S. 33° W.	3.9	S. 33° W.	4.6	S. 49° W.	4.5	S. 37° W.	4.6	S. 77° W.	4.6	S. 82° W.	3.7	S. 85° W.	2.9	S. 63° W.	2.2	S. 45° W.	7.1	S. 37° W.	5.5	S. 67° W.	9.4	S. 81° W.	5.4
1,500	S. 45° W.	4.5	S. 37° W.	4.7	S. 62° W.	4.5	S. 43° W.	4.5	S. 81° W.	5.5	S. 89° W.	4.3	S. 86° W.	3.7	S. 71° W.	3.1	S. 47° W.	6.0	S. 35° W.	5.4	S. 71° W.	10.2	S. 86° W.	5.7
2,000	S. 53° W.	4.3	S. 35° W.	4.0	S. 86° W.	5.6	S. 57° W.	5.0	S. 85° W.	6.3	S. 87° W.	5.2	N. 70° W.	5.9	S. 85° W.	4.6	S. 51° W.	4.1	S. 34° W.	4.3	S. 73° W.	10.8	S. 86° W.	7.2
2,500	S. 57° W.	4.9	S. 38° W.	4.3	N. 84° W.	7.2	S. 71° W.	5.8	S. 85° W.	6.3	S. 85° W.	5.8	N. 82° W.	7.7	N. 85° W.	6.6	S. 53° W.	3.6	S. 33° W.	3.7	S. 75° W.	14.5	S. 88° W.	9.9
3,000	S. 65° W.	5.8	S. 47° W.	5.5	N. 80° W.	9.4	S. 72° W.	6.7	S. 83° W.	6.8	S. 81° W.	7.9	N. 88° W.	9.8	N. 86° W.	8.5	S. 49° W.	3.3	S. 24° W.	3.6	S. 84° W.	15.4	S. 84° W.	12.4
3,500	S. 78° W.	6.8	S. 57° W.	5.0	N. 81° W.	12.3	S. 74° W.	7.6	S. 83° W.	6.5	S. 85° W.	7.3	N. 87° W.	10.8	N. 80° W.	11.0	S. 18° W.	2.7	S. 2° E.	2.5	N. 89° W.	14.3	S. 80° W.	12.4
4,000	S. 62° W.	10.0	S. 31° W.	7.8	N. 79° W.	11.8	S. 73° W.	7.2	N. 89° W.	7.1	.....	.....	N. 83° W.	10.6	N. 75° W.	10.8	S. 24° W.	5.7	S. 10° E.	0.9	N. 45° W.	16.5	N. 70° W.	8.0
4,500	S. 68° W.	17.3	S. 21° W.	8.8	N. 86° W.	11.9	S. 62° W.	8.0	W.	8.8	.....	.....	N. 81° W.	12.3	N. 70° W.	12.1	.....	.....	.....	.....	N. 45° W.	16.9	N. 47° W.	7.8
5,000	.....	.....	.....	.....	S. 45° W.	16.2	S. 63° W.	9.4	W.	7.6	.....	.....	W.	15.8	N. 75° W.	14.9	.....	.....	.....	.....	.....	.....	.....	.....

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

PRESSURE AND WINDS.

July, 1922, was, on the whole, free from notable atmospheric disturbances, and pressure conditions were remarkably uniform. The monthly averages were everywhere above normal, though not by any large values, and, compared with the preceding month of June, they were likewise higher by substantial amounts in all districts.

As is usual in the summer months, the pressure was highest over the South Atlantic and North Pacific coasts, but the mid-continent depression, common to the summer season, was less pronounced than usual.

The cyclonic disturbances were mainly weak, and, while discernible on the daily weather maps, only occasionally and for short periods assumed definite and important proportions. Likewise, anticyclones were usually weak and seldom pursued other than the more northerly courses in their eastward progress across the country.

On account of the slight filling up of the interior low area as compared with the normal, the barometric gradient between this and the normally high pressure during the summer months over the Southeastern States was less than usual. As a result, the tendency to southerly winds over the districts east of the Rocky Mountains was less pronounced than normal. On the whole, though, these winds were usually dominant in the districts referred to above, save along the immediate northern border, where they were mainly from the north. In the far Western States, the wind directions, though modified greatly, as usual, by topography, were nevertheless controlled by the high pressure over the Washington and Oregon coasts, giving them a trend from the northwest over the adjacent States, while in the Colorado Valley low pressure induced the usual circulatory winds over adjacent regions.

Along the central California coast, where strong northwest winds usually prevail during July, there was a notable absence of such winds during the current month, and light south to southwest winds prevailed for unusually long periods.

Local high winds, mostly associated with thunderstorms, occurred on numerous dates and in many localities, but few covered extensive areas. A list of the more important of these follows at the end of this section.

TEMPERATURE.

There were few marked features attending the temperature conditions existing during the month, save possibly the usually small extent of the daily fluctuations above or below the normal. The principal exception to this was in connection with the cool wave that extended over the central and southern districts during the 4th to 6th, at which time there were sharp falls in temperature and minimum readings as low as, and in a few cases lower than, previously observed in July were reported.

The first few days of the month were, on the whole, warmer than normal in the far West and over most eastern districts, and generally cooler than usual over the central districts. The period from the 5th to 11th, inclusive, was mainly cool from the Rocky Mountains eastward, particularly over the northern Great Plains, but there was continued warmth in the far West.

For the period 12th to 18th, inclusive, temperatures continued mainly higher than normal in the far West, attaining the highest values of the month about the 14th and 15th, when a temperature of 126° was observed in the desert region of California, and temperatures as high as ever observed in July were reported from southwestern Utah. From the lower Mississippi Valley northwestward to Montana and the Dakotas this period continued cooler than normal, while over the eastern and southern districts moderate temperatures were the rule.

The last decade of the month had no great departures from normal, but it was mostly cool in the far West, warm in the Rocky Mountain region, and variable in the districts to the eastward.

For the month as a whole, the average temperatures were below normal throughout the Great Central Valleys, most eastern districts, and over the middle Gulf States. They were well above normal over Texas and the far Southwest, the central valleys of California, and the central and eastern portions of Washington and Oregon. There were also small areas of the South Atlantic States and portions of New England and the adjacent Canadian Provinces that had averages for the month slightly above normal.

The warmest periods of the month were not confined to particular dates for extensive areas, and occurred in all parts of the month. The highest observed temperature was 126°, in southern California, and temperatures of 100° or slightly higher were reported from all except the Northern States. The lowest temperatures of the month were confined to a few periods, mainly from the 3d to 7th over most central and southern districts, and during the last decade in the far West, and over the Northern States.

Minimum temperatures of 32° or lower were observed in most of the mountain States, and in portions of the upper Lake region, damaging frosts being reported from extreme northern Michigan in the early part of the month.

PRECIPITATION.

Rainfall was frequent, and in many instances heavy, over most districts from the Rocky Mountains eastward during the first two decades of the month, and there were local heavy falls during the last decade in portions of the South Atlantic States and the lower Missouri Valley.

As is usually expected in a summer month, precipitation was mostly from thunderstorms, and the daily and monthly totals varied greatly over adjacent regions.

In the main, precipitation was sufficient for current needs over all regions where rainfall may be expected in July, and the amounts were mostly above normal over the interior States from the Rocky Mountains eastward and along the Atlantic coast from South Carolina to New Jersey. There were also liberal falls in Montana and portions of the Plateau regions. In portions of the central valleys, and locally elsewhere, the precipitation was extraordinarily heavy, notably in northwestern Missouri, where amounts in excess of 10 inches fell in less than 24 hours on the 10th and 11th, and in portions of Kansas, Michigan, and Virginia, where the month's falls were the greatest of record for July. On the other hand, a few localities, where liberal rains may be expected in July, had far less than normal, notably at Burlington, Vt., where the month was the driest known for July, and

at Corpus Christi, Tex., where no appreciable rain fell from the 1st to the 28th, inclusive, and in the far Northwest, notably in the State of Washington, where severe drought has persisted for an unusually long period. There was somewhat less than the normal rainfall over the Gulf States, but this was probably more beneficial than otherwise. There was a general deficiency from Ohio and West Virginia northeastward to New England, and generally over the Southwest, where the rainy period set in at the usual time, but the falls were much lighter than expected.

RELATIVE HUMIDITY.

The relative amount of moisture in the atmosphere was not materially different from the normal condition, although in the main the regions with an excess of precipitation had likewise higher than average relative humidity and the areas of most deficient precipitation had less, though there were marked exceptions in both cases. In general, the greatest excess was in the Missouri Valley, where it ranged up to 10 or 12 per cent, and the greatest deficiency in the far Northwest, where in some cases it was about the same.

SEVERE LOCAL STORMS.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the chief of bureau.]

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Bristow, Okla.	1-2			2		Thunderstorm	Battery of 30 or 40 oil tanks struck by lightning.	Dallas Morning News (Tex.). Official, U. S. Weather Bureau.
Baltimore, Md.	2	P. m.			$4,800,000	Electrical	Fires started by lightning burn 2 grain elevators and 2 piers of the Baltimore & Ohio R. R. Co.	Official, U. S. Weather Bureau.
Logan and Union Counties, Ill.	2					Wind	Trees, corn, and poles blown down.	Do.
Ardmore, Okla.	2					Thunder and wind.	Valuable shade and fruit trees uprooted, and buildings heavily damaged.	Dallas Morning News (Tex.).
Pittsburgh, Pa.	2					Thunderstorm	Streets and cellars flooded; car service interrupted by accumulation of débris.	Official, U. S. Weather Bureau.
Washington, D. C.	3	P. m.				Wind	Minor damage done by falling trees.	Evening Star (D. C.).
Harlem, Mont.	4	4 p. m.			20,000	Tornado and hail.	Damage to business houses, residences, and crops; small live stock killed.	Harlem News (Mont.).
Heath Springs, S. C.	4				2,000	Electrical	Warehouse and contents destroyed by lightning.	Official, U. S. Weather Bureau.
Pueblo, Colo., and vicinity.	6	P. m.				Wind	Buildings, trees, and overhead wires damaged by wind.	Pueblo Chieftain (Colo.).
Dodge City, Kans.	6	5:15 p. m.				do	Damage to uncut wheat, farm buildings and implements, plate glass windows, and trees; heavy loss sustained by telephone and power companies; 1 person injured.	Official, U. S. Weather Bureau.
Greeley County, Kans. (SW. quarter of).	7					Hail	All crops destroyed.	Do.
Lake Andes, S. Dak. (shores of).	8	P. m.		1	775,000–800,000	Tornado	Summer resorts on shores heaviest losers; village of St. Charles practically destroyed; many persons seriously injured.	Press and Dakotan (Yankton, S. Dak.).
Bonetraill and Squires, N. Dak.	8	P. m.				Rain and hail	Total and part losses reported by large number of farmers.	Williams County Farmers Press (Williston, N. Dak.).
New York, N. Y., and vicinity.	8	P. m.				Thunderstorm	Trees and poles blown down; number of cellars flooded in Jersey City.	Herald (New York).
Gregory and Charlesmix Counties, S. Dak., and Knox County, Nebr.	8-10			3	3,000,000	Thunderstorms and tornadoes.	Severe general damage: heavy loss in live stock; many persons injured.	Daily Journal and Evening Post (Chicago, Ill.).
Stoughton, Wis., and vicinity	9					Wind	A score of tobacco sheds blown down, trees damaged, and the electric light line out of commission.	Capital Times (Madison, Wis.).
Carroll and Rockland Counties, Ill., and Scott County, Iowa.	9					Electrical, wind, and rain.	Heavy damage to street car and telephone lines; crops also severely damaged; streets and country roads flooded. Damage in Davenport estimated at $4,000. In Carroll crops were damaged to the extent of $50,000 to $100,000. In Moline the damage is thousands of dollars.	Official, U. S. Weather Bureau; Moline Dispatch (Ill.).
Lone Star, S. C.	9				25,000	Electrical	Warehouse and contents damaged by lightning.	Official, U. S. Weather Bureau.
Menominee County, Mich., and Marinette, Wis.	9					Wind	Severe damage to crops, farm buildings, and machinery; damage estimated at thousands of dollars.	Menominee Herald Leader (Mich.).
Toledo, Ohio.	10	P. m.		2	25,000	Wind and rain	Damage to wires, trees, and crops; several persons injured.	Official, U. S. Weather Bureau.
Napoleon, Ohio.	10	P. m.		1		Wind	Thousands of dollars damage to crops and trees; child killed by falling limb.	Times (Toledo, Ohio).
Fort Wayne, Ind.	10	P. m.				Wind and rain	Overhead wires, trees, etc., heavily damaged.	Official, U. S. Weather Bureau.
Muncie, Ind.	10					Electrical	Some property damage; one man injured by lightning.	Indianapolis Star (Ind.).
Warsaw, Ind.	10	P. m.				Wind and rain	Three houses unroofed, trees blown down, and streets and basements flooded.	Do.
Waterloo, Ind.	10	3 p. m.				Wind	Several barns destroyed, trees and wires blown down, and windows broken.	Do.
Livingston, Ford, and Iroquois Counties, Ill.	10				71,000	do	Much damage to crops and property.	Official, U. S. Weather Bureau.
Kansas City, Mo.	10	P. m.			35,000	Thunderstorm	More than 8,000 telephone and electric light poles down, 25 street cars stalled, streets and basements flooded.	Do.
Swansea, S. C. (near)	10				2,000	Electrical	Barn and contents damaged by lightning.	Do.
Newton, Kans., and adjacent territory.	10					Wind, rain, and hail.	Heavy damage in oil fields; some property damaged; $500,000 in oil fields.	Wichita Beacon (Kans.).
Wichita, Kans., and vicinity.	10	P. m.				Wind and rain	Minor damage to property, trees, wires, and orchards.	Do.
El Dorado, Kans.	10	P. m.				do	Oil companies heaviest losers, 650 rigs leveled; lines of communication out of commission and crops damaged.	Do.
Chicago, Ill.	11	A. m.				Rain	Subways, basements, and streets flooded; car service crippled.	Evening Post (Chicago, Ill.); Official, U. S. Weather Bureau.
Salem, Ohio.	12			2		Electrical	Minor property damage.	Plain Dealer (Cleveland, Ohio).

Severe local storms—Continued.

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Weymouth, Conn.	13	P. m.		1		Rain and electrical	Buildings and trees slightly damaged.	Times (Hartford, Conn.).
Suffield, Conn.	13	P. m.				Rain and wind.	Damage to buildings by lightning; 1,000 acres of tobacco damaged by rain.	Do.
New York, N. Y., and vicinity.	13			3		Thunderstorm.	Considerable property destroyed, cellars flooded, streets and car tracks inundated.	Herald (N. Y.).
Denver, Colo. (near)	14	P. m.				Wind.	$30,000 damage to Fitzsimons Hospital; other minor damage.	Denver Post.
East central South Carolina.	14				$43,500	Electrical.	Buildings damaged by fire caused by lightning; 2 dairy cows killed.	Official, U. S. Weather Bureau.
Bon Homme County, S. Dak., and Knox County, Nebr.	16	P. m.		2		Wind, hail, and electrical.	Buildings and crops damaged.	Press and Dakotan (Yankton, S. Dak.).
Sioux Falls, S. Dak. (30 miles west of).	16					Hail.	Complete destruction of crops.	Do.
Colfax, Iowa.	16					Wind and rain.	Buildings blown down, windows broken, and lines of communication crippled.	Post (Washington, D. C.).
Ogden, Iowa.	16					do.	Telegraph and telephone wires down; considerable damage to crops.	Do.
Lancaster, Mo. (near)	16–17					Rain.	1,000 feet of railway track washed out; crops damaged.	Official, U. S. Weather Bureau.
Downing and Amoret, Mo.	16–17					Electrical and rain	Barns struck by lightning and burned; crops damaged.	Do.
New York, N. Y., and vicinity.	18	P. m.				Rain.	Traffic tied up by floods, some property damage, and several persons injured; damage on Staten Island estimated at $75,000.	Tribune (N. Y.).
Central and western Maine.	18	P. m.		1		Electrical and rain	General damage done by lightning and floods; traffic delayed; 1 man killed by lightning at Freeport.	Evening Express Advertiser (Portland, Me.).
Rockland, Me.	18	P. m.				do.	Two churches damaged by lightning and trolley cars held up.	Do.
Thornton, Tex., and near.	19	P. m.				Wind and rain.	Several houses blown down, windows shattered, and communication cut off.	Pensacola News (Fla.).
Macon, Ga.	19					Rain.	Considerable damage by flooding of streets and basements in business section.	Official, U. S. Weather Bureau.
Omaha, Nebr. (near)	22	A. m.				Electrical, wind, and rain.	Telephone and telegraph service crippled; trees only blown down.	Evening Post (Chicago, Ill.).
Macon, Ga.	22			1		Electrical and rain.	Moderate damage to property and shade trees.	Official, U. S. Weather Bureau.
Marion, Ky.	23	P. m.				Electrical, wind, and rain.	Many shade trees blown down and some property damage.	Crittenden Press (Ky.).
Monroe, Perry, Randolph, and St. Clair Counties, Ill.	23					Wind.	Trees uprooted, fruit shaken from trees, and other slight property damage.	Official, U. S. Weather Bureau.
Marion and Johnson Counties, Ill.	23					do.	Fruit and fruit trees damaged.	Do.
Evansville, Ind.	23			1		do.	Damage to crops, overhead wires, etc.	Do.
Rhode Island.	23	P. m.				Electrical and rain.	Streets and sidewalks washed out, basements flooded; public utilities suffer.	Do. Evening Bulletin (Providence, R. I.).
Harrisburg, Ill.	24			1	5,000	Wind.	General damage.	Official, U. S. Weather Bureau.
Savannah, Ga.	25					Wind and thunderstorm.	Street signs blown down and school building damaged by lightning.	Do.
Christian, Greene, Macoupin, and Morgan Counties, Ill.	26–30					Electrical.	Some live stock killed, and a number of barns fired by lightning.	Do.
Burns, Wyo. (SW. to NE. of).	27	P. m.			5,000	Wind.	General damage done.	Do.
York, Pa.	28					Hail.	Windows, fruits, and tobacco badly damaged.	Do.
Edgecombe County, N. C.	28	9:30 p. m.			50,000	do.	Damage to crops over considerable area.	Do.
Western Massachusetts.	28	P. m.				Electrical, rain and wind.	Heavy property damage; public utilities crippled.	Union (Springfield, Mass.).
Williston, N. Dak. (near)	28	P. m.				Hail.	Acres of crops destroyed from 25 per cent to total.	Williams County Farmers Press (Williston, N. Dak.).
Columbia, Mo.	29					Thunderstorm.	Public utilities crippled and much property damaged; several persons injured; damage occurred over 100 square miles.	Official, U. S. Weather Bureau.
Charles City, Iowa (10 miles NE. of).	30	5:15 p. m.			1,000	Tornado.	About 38 acres of oats ruined: farm houses and machinery damaged.	Do.
Columbus, Ohio (E. and S. of).	31				100,000	Thunderstorm, wind, and hail.	Buildings unroofed, telephone poles down, and much damage to crops: three girls injured.	Enquirer (Cincinnati, Ohio).
Dayton, Ohio.	31					Wind, rain, and hail.	Some damage to growing crops.	Official, U. S. Weather Bureau.
Dunkirk to Richmond, Ind.	31	A. m.				Hail.	Some property damage and corn and oat crops injured.	Do.
Union, S. C. (near)	31					Electrical.	Some live stock killed.	Do.

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

No storm warnings were issued during the month, as there was little activity in the movement of areas of low pressure. However, small-craft warnings were issued for portions of the Atlantic coast north of Cape Hatteras as follows: 1st, Delaware Breakwater to New London, Conn.; 2d Baltimore, Md., to Boston, Mass.; 6th, Rockland, Me., to Eastport, Me.; 8th, Norfolk, Va., to Eastport, Me.; 20th, on the New Jersey coast; 23d, Baltimore, Md., to Portland, Me.—*Charles L. Mitchell.*

CHICAGO FORECAST DISTRICT.

The month of July in the Chicago District, so far as special warnings are concerned, was comparatively eneventful.

On the 7th, at 10 a. m., southwest storm warnings were ordered displayed for the Lower Lakes and northwest warnings on Huron and Eastern Michigan. As the storm passed to the eastward with moderate intensity, the ensuing winds were mostly in the shape of thunder-squalls, with velocities ranging from 36 to 44 miles an hour on Lakes Huron and Erie. Because of the quick movement of the storm, the warnings were ordered down the following evening.

No frost occurred in any section and no general frost warnings were issued.

Advisory messages were continued during the month in the form of daily fire-weather forecasts, to the district forester at Missoula, Mont.; and special forecasts for three days in advance were sent daily for the benefit of the fruit growers in Door County, Wis., in connection with their spraying operations.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

Quiet weather conditions prevailed and no storm warnings were issued or required. Small-craft warnings, displayed on the central coast of Texas on the 9th, were justified.—*R. A. Dyke.*

DENVER FORECAST DISTRICT.

No special warnings were required or issued during the month, except fire-weather warnings which were distributed for the entire district on the evening of the 7th, when an area of low barometric pressure of considerable intensity was central in Montana and northern Idaho. On the morning of the 8th a maximum wind velocity of 42 miles per hour was reported at El Paso, and on the evening of the same date 30 miles at Albuquerque and 44 miles per hour at Cheyenne. The highest wind velocities for the month at Denver and Grand Junction, 38 miles per hour, also occurred on the 8th.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

All storms from the North Pacific during the month moved inland at a high latitude and did not materially affect the weather in this district.

Thunderstorms occurred in the Sierra Nevada and Plateau region from the 4th to the 6th, and again from the 17th to the 23d.

On the 2d the temperature at Roseburg, Oreg., reached 104°, equaling the record for the month at that station.

A peculiar feature of the month was the absence of northwesterly gales along the central California coast. Usually these are of nearly daily occurrence at Point Reyes, but this month, instead of strong northwesterly gales, light south to southwest winds prevailed for days at a time. The observer informed me he could find no similar record for so many consecutive days in July.

Fire-weather warnings were issued in northern California on the 14th and 26th, and were verified.—*G. H. Willson.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

Moderate floods occurred in the rivers of the South Atlantic States on account of frequent rains after the middle of the month. Warnings were issued wherever and whenever necessary, and no damage of consequence resulted. There were no other floods east of the Mississippi River except a short and harmless one in the upper Connecticut River on July 2. There were, however, several overflows of small streams at different times caused by torrential local rains. These occurred in Southern New England and the Middle Atlantic States, and the aggregate losses were more than $1,000,000, mostly in northeastern Pennsylvania, where the storm was the fourth destructive one within four weeks.

The destructive floods of the month occurred in the rivers of northwest Missouri, where all the rivers and smaller streams overflowed their banks after the torrential rains of July 9 and 10. At Maryville 10.82 inches of rain fell during the 24 hours ending at 7 a. m. July 10, at Chillicothe 5.18 inches fell on July 9 and 10, and at Brunswick 3.34 inches on the same dates.

The larger rivers that were in flood were the Grand, Nishnabotna, Nodaway, One Hundred and Two, and Platte, and it was reported that the latter was 1½ miles in width in places on July 12.

Crops suffered enormously, bridges and roads were washed away, railroad tracks were torn up, and traffic generally interrupted. Between 8,000 and 10,000 acres of farm lands were inundated, and the losses will run into millions of dollars. The losses from the Grand River flood alone were reported as having been about $2,000,000.

Warnings were sent out on July 10 as soon as the first reports of heavy rain had been received, but, although the flood conditions did not become serious until early morning of July 12, many farmers were unable to get their wheat out of the lowlands. Some worked all day and throughout the night and succeeded in saving a considerable quantity of wheat, but many thousands of bushels were carried down the swollen rivers. It was impossible to convince numbers of farmers that a destructive flood could occur in July, and these lost everything. However, as a whole, both farmers and others were quick to action as soon as the warnings had been received, and many have expressed their gratitude and thanks for the timely and accurate warnings, which were distributed largely by telephone. By 9:40 a. m. July 10, or within one hour after the warnings had been received at the Weather Bureau Office at St. Joseph, they had been repeated to more than 100 farmers living in the One Hundred and Two River Valley in Andrew, Buchanan, and Platte Counties.

The following report on the flood in the Grand River of Missouri was prepared by Mr. M. W. Hayes, meteorologist in charge of the Weather Bureau Office, St. Louis, Mo.:

THE GRAND RIVER FLOOD OF JULY, 1922.

The basin of the Grand River extends from south central Iowa southward to the Missouri River. It is a comparatively flat area, containing 7,891 square miles and sloping from an elevation of about 1,000 feet above mean sea level in Iowa to about 700 feet at Chillicothe and about 650 feet at the mouth of the river. There are two distinct subbasins extending as far southward as Chillicothe; the easterly one contains 2,194 square miles and is of an elongated shape; the distance from Chillicothe to its upper end in Iowa is 125 miles. The westerly subbasin has an area of 2,664 square miles, while the distance from Chillicothe northwestward to its upper extremity is 20 miles less than the length of the easterly division. These two subbasins combined form an area that is almost rectangular except for an acute angle—the upper part of the easterly division—that extends well up into Iowa. Chillicothe is in the southeastern corner of the area.

Rainfall in extreme northern Missouri and south central Iowa is at times unusually excessive in periods varying in duration from two or three days to a week between May 15 and July 15. From 1909 to 1922, inclusive, there have been five years (1909, 1915, 1917, 1919, and 1922) in which rainy periods have given precipitation ranging in amount from 4 to 12 inches over a large part of the watershed above Chillicothe.

In comparing flood heights in the Grand below Chillicothe the influence of the Missouri River has to be considered, for a high Missouri checks the discharge of the lower Grand, while a low Missouri permits a rapid discharge and cuts the flood height in the lower river very materially. For purposes of comparison the Chillicothe stages alone are considered. The Chillicothe gauge is a very short distance below the confluence of the east and west branches of the river and is too far away from the mouth of the main stream to be affected in any material way by Missouri River stages.

The highest flood known in the Grand and its two principal tributaries that meet at Chillicothe occurred in July, 1909. In that year a period of rains began on July 5 and continued at an excessive rate for three days. In most of the drainage basin above Chillicothe 4 to 11 inches of rain fell.

The second highest flood was in June, 1917. The rain that caused it began on June 1 and, with the exception of the 3d, fell daily through the 6th. The amounts ranged from 4.34 to 7.47 inches. As in the case of the 1909 flood, the heaviest rain was a short distance south of the Iowa line, and the lightest was in the lower part of the drainage area.

The third highest was in July, 1922. The rainfall had been deficient since the latter days of May, and both the Grand River system and the Missouri River were low on July 9, when excessive rains began over the northwestern part of the Grand River basin. In less than 24

hours 10 to more than 12 inches of rain fell in the extreme northwest part of the westerly subdrainage area above Chillicothe. In the remainder of the basin 3 to 6 inches fell. Most of the rain, and probably enough to cause a disastrous flood, fell in the 24 hours ending at 7 a. m. of the 10th. A very rapid rise began in the tributary streams on the 10th, and in the main stream as far south as Chillicothe on the 11th. Very high stages were general, except near the mouth of the river. The bottoms are broad throughout the system; all of them above Chillicothe were covered, and below the widely inundated area extended almost to the Missouri River. The water receded slowly, as is usual in this system, thus augmenting the seriousness of the situation.

The stage of the Missouri River was moderate throughout the flood in the Grand, and the discharge near the mouth of the Grand was sufficiently rapid to keep the maximum stage down to a level that was not more than 5 feet above bankful.

There are three rainfall charts inclosed.[1] They show the precipitation that caused the floods of July, 1909, June, 1917, and July, 1922. There is also forwarded herewith a tabular statement of the annual maximum stages of the Grand River at Chillicothe.

WARNINGS ISSUED.

At 10 a. m. of July 10, the following telegraphic warnings were issued:

To Pattonsburg, Gallatin, and Trenton, Mo.—Heavy rains upstream. River will rise rapidly and pass bankful stage.

To Chillicothe.—Heavy rains upstream. Grand will rise rapidly, passing flood stage in 36 hours.

To Brunswick.—Heavy rains over Grand, and in northwest Missouri. River will pass flood stage by Wednesday (12th).

At 3 p. m. of the same day, after receipt of additional rainfall reports, further warnings were telegraphed as follows:

To Pattonsburg, Gallatin, Trenton, and Chillicothe, Mo.—Very heavy rains falling in northern counties from Putnam to Nodaway. Amounts sufficient to give high flood. Disseminate widely.

To Brunswick.—Very heavy rains falling in northern counties from Putnam to Nodaway. Amounts sufficient to cause high flood above Brunswick. Rise at Brunswick depends upon action of Missouri, which can not be estimated until Tuesday (11th).

On the 11th a stage of 14 feet was forecast for Brunswick.

On the 12th a crest stage of 30 feet was forecast for Chillicothe, and the river observer at that place was asked to disseminate the information as widely as possible.

When the first warnings were telegraphed the stages were low. The Chillicothe stage was 5.3 feet, whch is 12.7 feet below bankful stage. All of the warnings were given as thorough a dissemination as possible. The Chillicothe Chamber of Commerce and the telephone companies in the basin spread the information among the farmers by telephone. The time that was available for the driving of live stock out of the bottoms and moving the shocked wheat was ample. Most of those having property of this kind in exposed places began to move it upon receipt of the first warning. There were some, however, who were doubtful that the river would rise high enough to cause any damage, and lost all of their bottom wheat and most of their live stock running in the bottoms.

Thousands of acres of growing corn were a total loss. Some corn on the edge of the flooded area survived the inundation, but in most of the bottom land the crop was covered three to six days and was killed. On account of the lateness of the season, replanting had to be confined to a few forage crops.

There was one human life lost during the flood, that of a boy of 17, who was drowned on July 12 while driving cattle from flooded lowlands near Brimson, Grundy County.

The following is a tabulation of the statistical reports concerning flood losses and the value of the warnings in Daviess, Grundy, Livingston, Carroll, and Chariton Counties, Mo.:

Damage to highways, bridges, farm buildings, etc.	[2] $80,000
Loss of crops, which may or may not have been housed	530,000
Loss of prospective crops, 57,300 acres	1,432,500
Loss of livestock or other movable property	[2] 11,500
Loss due to suspension of business, including wages of employees	87,000
Money value of property saved by warnings	1,790,000

Highest stages at Chillicothe for 1909 and for 1915 to 1922, inclusive. There are no records for the period 1910 to 1914, inclusive.

	Stage.		Stage.
1909	33.6	1919	29.8
1915	30.1	1920	26.9
1916	27.0	1921	19.2
1917	31.5	1922	30.5
1918	21.0		

[1] Not reproduced. [2] For Livingston County only.

There is inclosed herewith a copy of resolutions adopted by the Chamber of Commerce of Chillicothe, Mo., expressing its appreciation of the work of the Weather Bureau in connection with this flood.

THE HIGHWAY CITY—THE CHAMBER OF COMMERCE—COURTESY TOWN—CHILLICOTHE, MO.

BOARD OF DIRECTORS' MEETING, JULY 18, 1922—A RESOLUTION OF APPRECIATION TO ST. LOUIS WEATHER BUREAU.

Whereas the warning sent out by telegraph through the local station representative by the Government Weather Bureau at St. Louis, giving from 30 to 36 hours' notice in advance of a 30-foot flood stage in the Grand River Valley in Livingston County, caused by a heavy downpour about July 10th, in the northwest part of the State; and

Whereas said telegram contained the further warning to all farmers and others in the lowlands to make every effort to save their harvested crops, their live stock, and to remove same to the higher lands; and

Whereas many of our farmers heeded the warning and did save some of their crops and nearly all their live stock, while others, we regret to say, did not heed the warnings; and

Whereas the Chillicothe Chamber of Commerce, by the information contained in said Government Weather Bureau warning, was put in a position to cooperate in distributing this information to our rural district lowland farmers: Therefore be it

Resolved, At this a regular board of directors' meeting, held on the above date (motion made by E. O. Welch, seconded by W. C. Arnold, and passed unanimously), "That a proper resolution be prepared by the secretary commending the Government Weather Bureau office at St. Louis for furnishing advanced report and warning to the people of Livingston County from 30 to 36 hours, relative to the recent flood, so that they could get their stock and crops out of the lowlands prior to the arrival of the flood. And also to request that if the Government office at St. Louis will furnish the chamber of commerce with a copy of all future information of this nature which comes to their local representative, the chamber will be able to facilitate in getting this information out over the county much quicker."

BOARD OF DIRECTORS,
By HARRY W. GRAHAM, *Secretary*.

There was also a general overflow of the smaller streams of northeastern Nebraska on July 30, and according to press reports towns and farm lands were damaged to the extent of $1,000,000.

The rise in the Arkansas River and tributaries from the Wichita district southward was not serious except in the Little Arkansas River. The total damage reported was about $55,000, of which about $40,000 was in crops. Warnings were issued well in advance of the rises.

ANNUAL RISE OF THE COLUMBIA RIVER, 1922.

By R. C. MIZE, Meteorologist, Portland, Oreg.

Reports at the end of March showed practically the entire season's snowfall on the ground in the mountain areas. The depth was about average, the snow somewhat less compact than usual, streams unusually low, and the soil fairly well filled with moisture. Forecast was made at that time that with normal temperature conditions there should be a crest of about 20 feet at Portland, and that this stage might be exceeded should there be 10 days or more of continued hot weather late in May or early in June.

At the end of May an usually hot spell prevailed, the last four days of the month showing an excess of 56° above normal. At this time the river was 5 feet lower than on the same date of the preceding year. Moderately hot weather continued until June 8, by which time the stage was but 2 feet lower than that of one year before. The crest was reached at Portland on the average date, June 11. The flood stage was reached on May 21, one day later than the average, and continued six days less than the average. The crest was 0.1 foot higher than

the one and three day forecasts and 0.2 foot higher than the two-day forecast.

All the larger dikes held, and comparatively little tilled ground was flooded. The greatest item of loss reported was due to suspension of business, and of this about one-half was suffered by the salmon-fishing industry.

Flood stages were not reached on the Snake River, nor at Umatilla, Celilo, The Dalles, or Cascade Locks on the Columbia River.

There were three crests in the Snake River at Lewiston: 15.0, May 19; 15.6 May 26; and 16.1, June 7. The first and third were evidently caused by the Clearwater River. The highest stage at Lewiston was reached when the upper Columbia River at Wenatchee had approached within 1 foot of its crest.

Summaries of flood data and loss and damage are appended.

Flood data for 1922 and comparative data.

1922						Comparative data.				
Station.	River.	Flood stage.	Duration (days).	Crest height.	Date of crest.	Highest record.	Average date of crest.	Average height of crest.	Mean June, 1922.	June normal.
Weiser	Snake	14	0	11.6	May 27	26.5	May 31	11.5	8.3	6.6
Kamiah	Clearwater	14	4	14.4	June 6	15.4	May 24	13.5	10.8	9.6
Lewiston	Snake	22	0	16.1	June 7	26.6	May 30	16.1	12.6	11.6
Bonners Ferry	Kootenai	26	3	26.7	...do	32.7	June 9	24.8	22.0	20.8
Newport	Pend Oreille	16	23	18.9	June 15–17	24.9	June 12	16.2	17.2	14.2
Marcus	Columbia	24	44	30.5	June 18–19	33.8	June 22	30.5	28.8	27.3
Wenatchee	...do	40	10	40.4	June 15–18	58.0	June 14	38.5	38.1	34.0
Umatilla	...do	25	0	22.6	June 8	34.5	June 8	21.6	20.2	18.4
Celilo	...do	30	0	19.3	June 9	23.4	June 9	17.4	16.6	15.0
The Dalles	...do	40	0	38.2	...do	59.6	June 11	37.7	33.7	30.2
Cascade Locks	...do	46	0	30.2	June 9–10	49.6	June 10	29.0	26.2	23.5
Vancouver	...do	15	45	23.4	June 11	24.8	June 13	21.0	21.0	18.3
Portland	Willamette	15	43	22.4	June 11–12	33.0	June 11	20.4	20.1	17.6

Highest summer stages, Willamette River, Portland, Oreg.

Year.	Feet.	Year.	Feet.	Year.	Feet.	Year.	Feet.	Year.	Feet.
1876	28.2	1887	25.7	1896	23.8	1905	13.6	1914	16.8
1879	20.5	1888	18.2	1897	23.7	1906	13.4	1915	12.6
1880	27.3	1889	10.0	1898	20.7	1907	19.2	1916	23.9
1881	19.7	1890	20.1	1899	24.2	1908	21.2	1917	23.8
1882	25.1	1891	14.1	1900	17.8	1909	21.6	1918	19.2
1883	17.8	1892	19.3	1901	20.8	1910	19.1	1919	18.6
1884	20.2	1893	22.0	1902	20.8	1911	19.2	1920	14.8
1885	14.5	1894	33.0	1903	24.0	1912	19.7	1921	24.3
1886	20.0	1895	16.3	1904	20.8	1913	24.0	1922	22.4

Statistics of money loss by flood.

Kind of loss or damage.	In Portland.	Outside.	Total.
Buildings, etc	$1,795	$17,335	$19,130
Crops	.....	7,300	7,300
Prospective crops (acres, 4,186)	.....	39,845	39,845
Movable property	.....	4,605	4,605
Suspension of business	5,500	49,038	54,568
Total	7,295	118,153	125,448
Saved by warnings	112,500	25,515	138,015

Flood stages during July, 1922.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Connecticut:	*Feet.*			*Feet.*	
White River Junction, Vt	13	(1)	2	14.0	2
Roanoke:					
Weldon, N. C	30	21	21	31.0	21
Neuse:					
Smithfield, N. C	14	21	21	14.5	21
Cape Fear:					
Elizabethtown, N. C	22	21	21	22.5	21
Black:					
Kingstree, S. C	12	24	25	12.4	24
Santee:					
Rimini, S. C	12	8	9	12.5	9
Do	12	21	30	13.3	23–24
Ferguson, S. C	12	9	9	12.0	9
Do	12	19	(2)	13.0	25–26
MISSISSIPPI DRAINAGE.					
Arkansas:					
Ralston, Okla	12	13	16	13.4	15
Little Arkansas:					
Sedgwick, Kans	18	11	11	20.8	11
Neosho:					
Oswego, Kans	17	13	15	19.7	14
Yonkers, Okla	14	13	14	17.7	14
North Canadian:					
Woodward, Okla	3	3	3	3.3	3
Grand:					
Chillicothe, Mo	18	12	24	30.5	14
Brunswick, Mo	10	12	24	14.9	18
COLORADO DRAINAGE.					
Colorado:					
Parker, Ariz	7	(1)	18	9.3	1
PACIFIC DRAINAGE.					
Columbia:					
Marcus, Wash	24	(1)	13	27.0	1
Vancouver, Wash	15	(1)	4	16.7	1
Willamette:					
Portland, Oreg	15	(1)	2	15.9	1

[1] Continued from June. [2] Continued into August.

MEAN LAKE LEVELS DURING JULY, 1922.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., August 4, 1922.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during July, 1922:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.49	580.67	572.76	246.92
Above or below—				
Mean stage of June, 1922	+0.29	+0.13	−0.15	+0.17
Mean stage of July, 1921	−0.10	+0.23	−0.14	+0.55
Average stage for July, last 10 years	−0.14	−0.35	−0.20	+0.04
Highest recorded July stage	−1.33	−2.91	−1.65	−1.80
Lowest recorded July stage	+1.01	+0.77	+1.30	+2.33
Average relation of the July level to:				
June level	.....	+0.10	0.00	−0.10
August level	.....	+0.10	+0.20	+0.30

[1] Lake St. Clair's level: In July, 575.42 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JULY, 1922.

By J. B. KINCER, Meteorologist.

July, 1922, was on the whole favorable for farming operations in most sections of the country, although the first half of the month was rather too cool for warm-weather crops in the more northern States, and moisture was markedly deficient during most of the month in the Southwest. In addition, the latter part of the month was excessively warm in the lower Great Plains section, where moisture was deficient, and in some localities of that area destructive hot winds were experienced. Farm work made good progress generally, except for some delay to harvest in north-central States caused by heavy rainfall, and some hindrance to field work in the Southeast by continued wet soil.

Harvest and threshing of small grains made good progress under favorable weather conditions in practically all of the principal producing areas, and the weather was generally favorable for drying grain in shock, except that considerable damage occurred to oats in parts of the upper Mississippi Valley because of molding, rotting, and sprouting. Spring grains were benefited by showers in many of the more western districts the latter part of the month.

Temperature and moisture conditions were favorable for corn in the central valley States, except for some lack of moisture in parts of the Ohio Valley. It was rather cool for this crop during much of the month, however, in the central Northern States, and there was a serious lack of moisture in Oklahoma and central and western Texas and late corn deteriorated in that area. The rainfall near the close of the month in much of the upper Mississippi Valley was very favorable for corn.

The weather was mostly favorable for cotton, except where there was a lack of moisture in the more western portions of the belt and where it was too wet in parts of the east. The drought in Texas and Oklahoma had become rather serious at the close of the month and the progress of cotton was poor to only fair and considerable wilting and shedding were reported. Weevil, however, had become generally less active, particularly in the western portion of the belt where the weather had been warm and dry, although they continued numerous in most sections and were doing much damage in many localities. The weather was very favorable for picking in southern Texas, and bolls were reported as opening rapidly in southern Georgia at the close of the month.

There was sufficient moisture for most truck crops in the Central and Eastern States, but rain was badly needed in the Southwest, and moisture was deficient during parts of the month in portions of the Ohio Valley.

Grasses and ranges were rather unfavorably affected by dryness in the central Rocky Mountain States, although considerable rain fell in this area the latter part of the month, and at the same time showers improved the range in the northern and northwestern Great Plains. Ranges were very unfavorably affected by continued dry weather in the Southwest, although there was some relief by showers near the close of the month in much of Arizona and parts of New Mexico. Droughty conditions continued in the far Northwestern States.

CLIMATOLOGICAL TABLES.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 176 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, 75th meridian time, and for about 37 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives, for about 35 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, and depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January, 1902, pages 13–16.

Chart I.—*Tracks of centers* of ANTICYCLONES; and

Chart II.—*Tracks of centers* of CYCLONES. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th meridian time. Within each circle is also given (Chart I) the last three figures of the highest barometric reading, or (Chart II) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea-level and standard gravity. The inset map in Chart I shows the departure of monthly mean pressure from normal and the inset in Chart II shows the change in mean pressure from the preceding month.

Chart III.—*Temperature departures.* This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart IV.—*Total precipitation.* The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated, or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.00. The inset on this chart shows the departure of the monthly totals from the corresponding normals.

Chart V.—*Percentage of clear sky between sunrise and sunset.* The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VI.—*Isobars at sea level, average surface temperatures, and prevailing wind directions.* The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 8 a. m.—and 8 p. m.—readings at stations taking two observations daily, and to the 8 a. m.—or the 8 p. m.—observation, respectively, at stations taking but

a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The sea level temperatures are now omitted and average surface temperatures substituted. The isotherms can not be drawn in such detail as might be desired, for data from only the regular Weather Bureau stations are used.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VII.—*Total snowfall.* This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given.

Chart VII is published only when the snowfall is sufficiently extensive to justify its preparation.

Charts VIII, IX, etc.—*North Atlantic weather maps of particular days.*

CONDENSED CLIMATOLOGICAL SUMMARY.[1]

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July, 1922.

Section.	Temperature.								Precipitation.					
			Monthly extremes.								Greatest monthly.		Least monthly.	
	Section average.	Departure from the normal	Station.	Highest.	Date.	Station.	Lowest.	Date.	Section average.	Departure from the normal.	Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.9	0.0	Madison	100	[2] 27	Riverton	53	5	4.29	−1.06	Spring Hill	12.85	Wetumpka	1.76
Arizona	81.5	+1.6	Parker	119	6	Alpine	39	28	1.79	−0.69	Douglas	6.29	Yuma Citrus Station	0.00
Arkansas	80.2	+0.3	Subiaco	106	31	2 stations	48	5	4.12	+0.20	Marked Tree	8.90	Mena	0.96
California	73.4	+0.2	Greenland Ranch	126	15	Portola	28	22	0.15	+0.07	Campo	7.10	114 stations	0.00
Colorado	66.3	+3.5	Two Buttes	105	16	2 stations	27	[2] 7	1.88	−0.33	Wray	5.15	Delta	0.04
Florida	80.7	−0.4	Orlando	101	31	De Funiak Springs	57	7	6.84	−0.89	Pinellas Park	16.02	Sand Key	1.68
Georgia	80.3	+0.2	2 stations	101	[2] 29	Blue Ridge	57	6	4.96	−0.81	Clayton	10.04	Albany	1.60
Hawaii														
Idaho	68.0	+1.1	Kooskia	113	30	Stanley	25	16	0.49	−0.26	Grace	2.11	Lapwai	0.00
Illinois	75.0	−0.9	2 stations	102	[2] 27	Sycamore	41	8	3.69	+0.25	Freeport	8.00	La Salle	1.20
Indiana	74.2	−1.1	Seymour	101	16	2 stations	43	[2] 4	3.49	+0.04	Jeffersonville	9.05	Kokomo	0.80
Iowa	71.5	−2.6	Burlington	98	9	Estherville	40	7	6.31	+2.35	Mount Ayr	11.72	Northwood	3.13
Kansas	77.0	−1.1	Atwood	109	15	Oakley	42	7	5.07	+1.49	Winfield	13.62	Scott City	0.71
Kentucky	76.4	−0.3	Paducah	102	[2] 28	2 stations	47	5	4.77	+0.47	Cherokee Park	9.06	Maysville	1.55
Louisiana	81.4	−0.4	Plain Dealing	103	31	Calhoun	52	5	5.85	−0.46	Schriever	12.25	Calhoun	2.34
Maryland-Delaware	74.7	−0.4	2 stations	99	11	2 stations	43	6	5.82	+1.37	Cambridge, Md	11.78	Western Port, Md	1.83
Michigan	67.1	−1.4	Pontiac	100	24	Houghton Lake (near).	29	4	3.82	+0.71	Escanaba	7.37	Pontiac	0.48
Minnesota	67.3	−1.7	Fergus Falls	100	14	2 stations	38	3	2.26	−1.40	Grand Marais	5.35	Milaca	0.40
Mississippi	80.5	−0.2	5 stations	101	[2] 12	Edinburg	53	5	4.64	−0.42	Hickory	10.35	Agricultural College	1.32
Missouri	76.8	−0.7	Caruthersville	103	[2] 24	Goodland (2)	46	4	5.85	+1.82	Grant City	17.68	St. Louis (No. 2)	1.92
Montana	65.8	−0.4	Glendive	103	19	Philipsburg	29	13	1.73	+0.48	Wibaux	4.45	Fortine	0.34
Nebraska	72.6	−2.0	2 stations	106	[2] 14	Gordon	35	12	4.54	+1.10	Blair	9.08	Kimball	1.08
Nevada	74.1	+1.1	Logandale	116	5	Rye Patch	33	26	0.54	+0.19	Lamoille	1.80	Arthur	0.00
New England	68.4	−0.5	Torrington, Conn	95	13	Garfield, Vt	36	30	3.33	−0.29	Lawrence, Mass	7.17	Burlington, Vt	0.98
New Jersey	73.0	−0.7	Sussex	98	12	Layton	44	30	5.79	+1.00	Plainfield	9.26	Trenton	2.29
New Mexico	74.0	+1.3	Orogrande	110	[2] 11	Chama	30	[2] 9	1.32	−1.25	Aurora	4.59	Lindrith	0.00
New York	69.1	−0.5	Dansville	100	12	3 stations	37	[2] 10	3.29	−0.63	Bedford Hills	12.49	Copenhagen	0.63
North Carolina	76.8	+0.5	Goldsboro	100	1	3 stations	50	[2] 6	6.97	+1.05	Eagletown	12.52	Cullowhee	2.40
North Dakota	65.6	−1.9	Napoleon	100	14	Napoleon	30	7	2.40	−0.21	Larimore	6.15	Walhalla	0.60
Ohio	72.9	−0.9	Green	99	27	Wooster	41	5	3.70	−0.15	Hillsboro	8.45	Wauseon	1.25
Oklahoma	81.7	+0.7	Frederick	112	31	Arapoho	50	4	4.08	+0.97	Vinita	9.85	Mangum	0.44
Oregon	68.3	+2.3	Umatilla	114	3	Lapine	21	23	0.05	−0.52	2 stations	0.59	60 stations	0.00
Pennsylvania	71.9	−0.2	5 stations	98	[2] 11	West Bingham	38	30	3.68	−0.53	Springdale	7.58	West Bingham	1.45
South Carolina	79.9	+0.1	2 stations	101	[2] 2	2 stations	58	6	7.20	+1.22	Society Hill	12.58	Parris Island	3.50
South Dakota	69.2	−1.7	Pollock	104	14	Pollock	33	7	3.86	+0.55	Kadoka	8.82	Britton	0.44
Tennessee	77.4	−0.1	Perryville	101	28	Waynesboro	48	5	5.58	+0.86	Cedar Hill	10.56	Loretto	1.05
Texas	83.4	+0.5	3 stations	110	[2] 21	3 stations	53	[2] 4	1.74	−0.99	Beaumont	10.16	6 stations	0.00
Utah	71.6	+0.9	St. George	112	15	East Portal	32	2	0.75	−0.17	Farmington	2.16	Black Rock	0.00
Virginia	75.3	−0.2	Chatham	99	2	Burkes Garden	48	7	6.66	+2.22	Newport News	15.25	Manassas	2.20
Washington	67.7	+1.7	2 stations	111	3	Paradise Inn	32	24	0.03	−0.72	Locke	0.61	86 stations	0.00
West Virginia	72.9	−0.1	Wheeling	99	12	Bayard	43	6	4.53	−0.19	Cheat Bridge	8.05	Dam 26, Ohio River	1.16
Wisconsin	67.1	−2.1	Beloit	99	9	Grantsburg	31	28	3.85	+0.22	New London	7.68	Amery	1.39
Wyoming	64.1	−0.9	3 stations	102	[2] 14	Foxpark	21	12	1.59	+0.24	Newcastle	5.78	Green River	0.01

[1] For description of tables and charts, see REVIEW, January, 1921, p. 41.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau Stations, July, 1922.*

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dewpoint. | Mean relative humidity. | Precipitation. | | | Wind. | | | | | | | | | | | |

TABLE 1.—*Climatological data for Weather Bureau Stations, July, 1922*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dewpoint.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.=2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F*		*° F*	*° F.*		*° F*	*° F.*		*° F.*	*° F.*	*%*	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
							75.9	**−0.8**											**71**	**4.14**	**+0.1**										**5.2**		
Chattanooga	762	189	213	29.27	30.06	+.04	77.8	−0.6	95	28	87	61	5	69	24		70	67	75	3.65	−0.2	15	4,421	sw.	44	nw.	23	7	16	8	5.5	0.0	0.0
Knoxville	996	102	111	29.03	30.06	+.04	77.3	+1.1	93	11	86	60	5	68	24		70	67	77	4.02	−0.2	12	4,074	sw.	32	s.	15	2	13	16	7.0	0.0	0.0
Memphis	399	76	97	29.65	30.07	+.07	80.0	−0.7	96	28	87	61	4	73	19		72	69	74	3.71	+0.2	6	5,255	sw.	40	nw.	23	8	10	13	5.9	0.0	0.0
Nashville	546	168	191	29.48	30.05	+.05	78.2	−0.9	95	28	88	58	5	69	28		70	66	71	6.15	+1.8	12	5,025	sw.	42	nw.	23	10	15	6	5.0	0.0	0.0
Lexington	989	193	230	29.00	30.04	+.03	75.8	−0.8	93	27	85	55	5	67	23					2.13	−2.3	8	8,617	sw.	41	sw.	12	11	14	6	4.5	0.0	0.0
Louisville	525	219	255	29.47	30.04	+.04	77.0	−1.6	94	27	86	57	5	68	23	68	64	68		7.79	+4.0	8	6,707	s.	40	ne.	27	13	12	6	4.3	0.0	0.0
Evansville	431	139	175	29.58	30.04	+.04	78.5	−0.8	96	28	88	56	4	69	23	70	65	67		6.39	+2.6	8	6,571	sw.	68	w.	23	9	18	4	5.1	0.0	0.0
Indianapolis	822	194	230	29.15	30.02	+.03	74.6	−1.6	90	27	84	54	4	66	25	66	61	65		2.67	−1.5	9	7,325	sw.	34	sw.	10	14	10	7	4.6	0.0	0.0
Royal Center	736	11	55	29.23	30.01	.....	71.6	.....	92	9	82	47	4	61	35					3.24	.....	9	5,881	n.	60	w.	10	9	11	11	5.7	0.0	0.0
Terre Haute	575	96	129	29.38	29.98	.....	76.0	.....	95	27	86	52	4	66	27	66	62	65		2.41	.....	10	6,081	s.	27	sw.	10	6	16	9	5.2	0.0	0.0
Cincinnati	628	11	51	29.37	30.03	+.03	75.4	−0.3	96	27	86	53	5	65	29	....	65	69		2.45	−1.1	8	4,578	sw.	24	sw.	11	14	9	8	4.4	0.0	0.0
Columbus	824	179	222	29.17	30.03	+.03	73.7	−1.2	92	10	83	52	5	64	25	66	62	67		2.29	−1.4	8	6,891	sw.	36	nw.	12	10	17	4	4.7	0.0	0.0
Dayton	899	181	216	29.06	29.99	.....	74.2	−2.0	92	27	84	51	5	64	26	66	61	65		4.49	+1.2	8	6,415	ne.	50	ne.	31	19	8	4	3.6	0.0	0.0
Elkins	1,947	59	67	28.05	30.04	+.03	70.4	−0.1	90	12	80	50	6	60	33	65	63	86		5.75	+1.1	14	2,514	w.	21	w.	23	6	15	10	6.1	0.0	0.0
Parkersburg	638	77	84	29.40	30.05	+.04	75.3	−0.3	93	27	85	53	6	66	28	67	65	76		3.65	−1.0	14	3,093	se.	27	nw.	12	11	9	11	5.6	0.0	0.0
Pittsburgh	842	353	410	29.14	30.02	+.02	73.9	−0.7	93	12	83	55	5	65	27	65	61	67		2.80	−1.6	8	6,773	sw.	54	sw.	1	10	13	8	5.4	0.0	0.0
Lower Lake region.							**71.0**	**−0.6**											**69**	**2.66**	**−0.7**										**4.8**		
Buffalo	767	247	280	29.20	30.02	+.05	70.1	−0.1	91	12	77	54	4	63	23	63	59	70		2.52	−0.9	9	9,050	sw.	60	sw.	12	9	11	11	5.7	0.0	0.0
Canton	448	10	61	29.52	29.98	.....	68.7	−1.8	89	12	78	49	29	59	29	.....	.....	.....		1.86	−1.4	9	5,877	sw.	39	nw.	12	17	10	4	3.5	0.0	0.0
Oswego	335	76	91	29.64	30.00	+.04	68.8	−0.8	89	11	76	55	9	62	26	64	61	76		2.56	−0.7	9	5,369	s.	25	sw.	17	15	7	9	4.5	0.0	0.0
Rochester	523	86	102	29.46	30.02	+.05	70.6	−0.1	93	11	79	53	5	62	28	63	58	66		2.17	−0.9	9	4,852	sw.	27	w.	1	13	13	5	4.5	0.0	0.0
Syracuse	597	97	113	29.40	30.04	+.07	69.6	−1.2	90	12	78	53	9	61	25	.....	.....	.....		2.39	−1.3	7	6,016	s.	28	sw.	17	10	12	9	5.2	0.0	0.0
Erie	714	130	166	29.26	30.01	+.03	71.5	−0.3	93	11	79	53	5	64	24	64	60	67		4.03	+0.8	12	7,792	n.	40	sw.	12	11	16	4	4.7	0.0	0.0
Cleveland	762	190	201	29.22	30.02	+.03	71.6	+0.2	90	11	78	52	5	65	24	64	59	66		3.98	+0.4	9	7,591	n.	36	nw.	17	8	15	8	5.2	0.0	0.0
Sandusky	629	62	103	29.35	30.02	+.03	73.2	−0.4	92	10	81	54	5	66	29	.....	.....	.....		2.60	−1.2	9	7,368	sw.	46	sw.	11	9	18	4	4.6	0.0	0.0
Toledo	628	208	243	29.36	30.03	+.04	72.3	−0.9	90	10	81	51	4	64	25	64	59	67		2.55	−0.7	11	8,629	sw.	73	sw.	10	13	15	3	4.5	0.0	0.0
Fort Wayne	856	113	124	29.12	30.03	.....	72.1	−1.3	90	10	82	51	5	62	29	64	60	69		4.08	.....	10	5,879	sw.	55	sw.	10	8	15	8	5.4	0.0	0.0
Detroit	730	218	245	29.25	30.02	+.04	72.6	+0.5	89	10	81	53	4	65	22	64	60	69		1.99	−1.5	12	6,581	sw.	54	sw.	10	7	18	6	5.1	0.0	0.0
Upper Lake region.							**66.8**	**−1.2**											**72**	**3.69**	**+0.6**										**5.3**		
Alpena	609	13	92	29.35	30.02	+.05	64.4	−1.4	85	16	73	43	4	56	32	60	56	75		3.56	+0.5	9	7,392	se.	42	w.	7	7	14	10	5.5	0.0	0.0
Escanaba	612	54	60	29.33	29.98	+.01	64.0	−2.5	78	27	71	45	4	57	21	60	57	78		7.37	+4.0	11	6,439	s.	43	ne.	7	10	10	11	5.5	0.0	0.0
Grand Haven	632	54	89	29.33	29.99	+.01	67.4	−2.3	89	9	75	48	4	60	38	62	59	74		3.22	+0.6	8	6,505	w.	33	s.	7	10	13	8	5.1	0.0	0.0
Grand Rapids	707	70	87	29.26	30.01	+.03	71.2	−1.4	89	9	81	49	4	62	33	62	57	62		4.05	+1.4	9	5,646	w.	34	nw.	7	6	16	9	5.9	0.0	0.0
Houghton	684	62	99	29.21	29.96	.00	63.2	−2.1	85	14	72	45	7	54	29	.....	.....	.....		2.10	−1.0	12	6,396	w.	35	w.	15	9	11	11	5.8	0.0	0.0
Lansing	878	11	62	29.08	30.00	.....	69.8	−1.3	90	10	82	44	4	58	32	62	58	70		2.57	−0.6	8	3,258	nw.	22	sw.	12	8	14	9	5.6	0.0	0.0
Ludington	637	60	66	29.31	30.00	.....	65.4	.....	86	9	73	46	4	58	33	61	58	76		3.73	.....	12	5,892	s.	38	sw.	9	16	10	5	4.2	0.0	0.0
Marquette	734	77	111	29.21	30.01	+.05	63.0	−1.9	85	15	71	44	7	55	31	58	54	76		3.49	+0.4	14	4,738	nw.	25	se.	9	8	9	14	6.2	0.0	0.0
Port Huron	638	70	120	29.23	30.02	+.04	68.9	−0.1	88	10	78	46	5	60	28	63	59	73		2.01	−0.7	11	6,802	ne.	35	w.	10	9	18	4	4.2	0.0	0.0
Saginaw	641	69	77	29.32	30.01	.....	69.4	.....	86	10	80	45	4	58	29	63	56	64		3.21	−0.5	9	5,277	nw.	34	sw.	12	10	10	11	5.2	0.0	0.0
Sault Sainte Marie	614	11	52	29.31	30.00	+.03	61.6	−0.3	85	16	71	42	4	52	33	57	54	80		5.44	+2.7	13	4,587	nw.	36	se.	9	11	10	10	5.4	0.0	0.0
Chicago	823	140	310	29.14	30.01	+.03	73.3	−0.6	93	9	80	60	4	67	28	64	59	63		4.00	+0.4	7	7,241	ne.	38	s.	9	12	10	9	4.7	0.0	0.0
Green Bay	617	109	144	29.32	29.98	+.01	68.2	−1.3	84	21	77	50	4	59	24	61	57	71		5.88	+2.0	13	7,115	s.	64	nw.	30	7	16	8	5.8	0.0	0.0
Milwaukee	681	125	139	29.27	30.00	+.03	69.8	+0.1	92	9	77	55	9	63	37	62	58	67		2.49	−0.5	11	5,898	sw.	36	se.	9	11	10	10	5.4	0.0	0.0
Duluth	1,133	11	47	28.77	29.97	+.02	63.6	−0.3	84	14	73	44	4	54	33	58	55	74		2.30	−1.4	12	7,985	ne.	36	ne.	9	12	11	8	5.0	0.0	0.0
North Dakota.							**66.8**	**−2.0**											**68**	**2.12**	**−0.8**										**5.0**		
Moorhead	940	50	58	28.96	29.96	+.02	67.3	−1.4	92	14	78	45	7	56	32	60	55	67		1.65	−2.1	8	4,782	nw	24	nw.	17	3	18	10	6.1	0.0	0.0
Bismarck	1,674	8	57	28.24	30.00	+.07	67.9	−1.9	95	14	80	40	7	56	35	60	55	67		2.77	+0.6	10	5,094	nw.	38	nw.	14	12	16	3	4.6	0.0	0.0
Devils Lake	1,482	11	44	28.40	29.95	+.02	65.7	−2.4	93	14	78	42	8	53	35	59	54	70		0.87	−2.9	9	5,765	nw.	33	n.	25	17	8	6	4.3	0.0	0.0
Ellendale	1,457	10	56	28.43	29.98	.....	66.4	.....	91	14	79	42	7	54	36	.....	.....	.....		1.54	.....	7	7,456	nw.	50	nw.	29	11	15	5	4.7	0.0	0.0
Grand Forks	835	12	89	.....	.....	.....	66.1	.....	92	14	78	44	7	54	35	.....	.....	.....		3.50	.....	13	.....	.....	.....	.....	.....	.....	11	13	7	.....	0.0	0.0
Williston	1,878	41	48	28.00	29.94	+.02	66.4	−2.5	95	14	78	47	10	54	38	58	53	66		3.18	+1.2	12	4,301	n.	28	se.	8	9	15	7	5.1	0.0	0.0
Upper Mississippi Valley.							**73.4**	**−1.9**											**67**	**4.24**	**+0.6**										**5.3**		
Minneapolis	918	102	208	29.00	29.96	.....	70.0	.....	91	30	79	52	7	61	26	.....	.....	.....		1.67	−2.1	8	7,087	nw.	41	s.	5	5	15	11	6.0	0.0	0.0
St. Paul	837	236	261	29.08	29.97	+.02	68.8	−3.3	91	30	78	51	3	59	29	.....	.....	.....		2.32	−1.1	7	7,394	w.	42	se.	9	9	17	5	5.2	0.0	0.0
La Crosse	714	11	48	29.22	29.97	+.01	69.0	−3.6	86	9	79	49	4	59	31	.....	.....	.....		2.08	−2.0	9	2,727	se.	20	se.	5	9	8	14	6.3	0.0	0.0
Madison	974	70	78	28.99	30.01	+.04	69.6	−2.8	90	9	78	55	9	62	35	63	59	73		6.09	+2.0	12	5,290	nw.	35	se.	9	6	11	14	6.5	0.0	0.0
Wausau	1,247	4	.....	28.69	30.01	.....	65.9	.....	84	21	76	46	3	56	30	.....	.....	.....		3.49	.....	7	.....	se.	.....	.....	.....	12	7	12	5.7	0.0	0.0
Charles City	1,015	10	49	28.94	30.00	+.04	68.7	−4.8	86	9	79	47	3	58	32	63	59	72		7.25	+3.7	14	3,532	sw.	23	sw.	5	10	12	9	5.2	0.0	0.0
Davenport	606	71	79	29.36	30.01	+.04	74.2	−1.2	95	9	84	55	3	65	27	65	60	64		5.66	+2.1	10	4,464	nw.	42	s.	16	12	11	8	5.4	0.0	0.0
Des Moines	861	84	97	29.10	29.99	+.03	73.0	−2.5	90	31	82	53	4	64	28	65	61	68		7.13	+3.3	13	4,477	s.	37	sw.	9	11	10	10	5.2	0.0	0.0
Dubuque	698	81	96	29.29	30.02	+.05	71.0	−3.1	92	9	80	50	8	62	28	64	60	70		6.01	+1.7	14	3,895	nw.	22	s.	15	8	11	12	5.7	0.0	0.0
Keokuk	614	64	78	29.35	30.02	+.04	75.5	−1.5	96	9	85	57	4	62	26	66	61	62		6.35	+2.3	7	4,528	s.	26	n.	12	11	9	11	5.4	0.0	0.0
Cairo	358	87	93	29.64	30.01	+.01	78.6	0.0	95	28	86	58	4	71	21	71	68	72		4.49	+1.0	5	4,899	s.	27	nw.	23	9	8	14	5.6	0.0	0.0
Peoria	609	11	45	29.36	30.02	+.04	74.7	−0.7	97	9	86	50	4	64	35	66	62	66		3.06	+0.1	6	3,428	s.	23	s.	9	16	11	4	3.4	0.0	0.0
Springfield, Ill.	644	10	91	29.33	29.99	+.01	76.4	−0.1	97	9	87	55	4	66	29	66	61	63		2.56	−0.3	11	5,386	s.	26	s.	9	14	8	9	4.8	0.0	0.0
Hannibal	534	74	109	29.44	30.00	+.02	75.8	−1.6	96	22	86	54	8	66	31	.....	.....	.....		2.26	−1.5	9	5,607	sw.	36	sw.	11	11	12	8	4.8	0.0	0.0
St. Louis	567	265	303	29.41	30.00	+.01	78.8	+0.2	96	31	88	60	4	70	26	68	63	61		2.42	−1.0	9	7,960	s.	42	s.	9	8	15	8	5.0	0.0	0.0
Missouri Valley.							**73.9**	**−1.8**											**69**	**4.60**	**+0.8**										**4.7**		
Columbia, Mo.	781	11	84	29.18	30.00	+.02	75.8	−1.6	96	22	86	50	4	65	31	.....	.....	.....		3.49	−0.2	10	4,385	s.	44	w.	29	16	8	7	4.6	0.0	0.0
Kansas City	963	161	181	28.98	29.98	+.01	76.9	−0.7	95	29	86	59	3	68	23	69	65	69		4.66	−0.2	11	6,163	s.	56	nw.	29	12	16	3	4.4	0.0	0.0
St. Joseph	967	11	49	28.96	29.97	.....	76.1	.....	94	31	86	53	4	66	29	68	64	70		4.16	.....	9	4,975	se.	48	nw.	11	17	11	3	3.8	0.0	0.0
Springfield, Mo.	1,324	98	104	28.64	30.02	+.04	76.4	0.0	95	22	85	57	4	68	25	69	65	71		6.15	+1.4	11	6,124	s.	31	nw.	25	20	9	2	3.3	0.0	0.0
Iola	984	11	50	28.95	29.97	.00	77.6	−0.5	97	28	88	54	4	67	32	.....	.....	.....		3.99	+0.1	10	3,976	s.	36	n.	25	9	17	5	4.9	0.0	0.0
Topeka	987	92	107	.....	.....	.....	76.4	−1.2	95	29	86	57	4	67	26	.....	.....	.....		8.04	+3.2	11	6,393	s.	44	nw.	11	13	11	7	4.5	0.0	0.0
Drexel	1,299	10	54	28.61	29.98	.....	72.0	.....	91	15	82	50	3	62	28	.....	.....	.....		4.51	.....	12	5,918	s.	36	sw.	9	9	12	10	5.3	0.0	0.0
Lincoln	1,189	11	84	28.74	29.97	+.02	73.8	−2.6	94	21	85	54	3	63	31	66	62	69		6.23	+2.4	15	5,969	s.	52	n.	22	9	15	7	5.1	0.0	0.0
Omaha	1,105	115	122	28.83	29.99	+.04	74.0	−2.5	91	16	83	56	3	65	27	67	63	70		5.60	+1.3	13	4,534	se.	35	nw.	29	11	15	5	4.5	0.0	0.0
Valentine	2,598	47	54	27.33	30.00	+.07	70.1	−3.1	94	30	82	42	12	58	35	62	57	69		3.89	+0.5	12	5,608	s.	49	nw.	16	11	13	7	4.7	0.0	0.0
Sioux City	1,135	94	164	28.80	29.98	+.03	71.7	−2.5	92	23	81	50	3	62	33	64	59	66		5.97	+2.4	9	7,131	s.	48	se.	8	8	13	10	5.8	0.0	0.0
Huron	1,306	59	74	28.63	30.00	+.06	70.6	−1.2	94	30	82	47	7	59	34	62	58	67		1.15	−1.8	10	5,493	se.	36	se.	8	12	12	7	4.3	0.0	0.0
Pierre	1,572	70	75	28.34	29.97	+.04	72.0	−3.3	95	30	83	49	7	61	33	64	59	68		2.84	+0.5	13	5,382	e.	45	nw.	24	11	12	8	4.8	0.0	0.0
Yankton	1,233	49	57	28.67	29.96	+.02	72.0	−2.1	95	15	82	50	7	62	32	.....	.....	.....		3.17	−0.4	13	4,532	nw.	32	s.	8	7	17	7	5.5	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau Stations, July, 1922*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dewpoint.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Northern Slope.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F*		° *F*	° *F.*		° *F*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
							67.1	**−0.9**										**58**	**2.21**	**+0.6**									**4.1**		
Billings	3,140	5					69.9	.....	102	18	87	42	17	53	56	.....	.....	.....	2.24	.....	10	.....	.....	.....	.....	.....	12	15	4	.....	0.0	0.0
Havre	2,505	11	44	27.39	29.99	+.08	67.2	−1.1	98	3	81	45	11	53	45	56	50	60	2.76	+0.8	10	4,117	sw.	46	n.	4	16	12	3	3.6	0.0	0.0
Helena	4,110	87	112	25.88	30.00	+.07	66.0	−0.6	93	31	80	46	17	52	39	53	44	52	1.32	+0.2	8	5,411	sw.	39	n.	4	13	9	9	4.5	0.0	0.0
Kalispell	2,973	48	56	26.96	29.96	+.03	64.6	+0.3	94	3	80	45	11	50	41	51	49	51	0.81	0.0	4	4,307	nw.	34	sw.	7	19	11	1	2.9	0.0	0.0
Miles City	2,371	26	48	27.50	30.00	+.08	72.8	−0.1	98	19	87	46	11	59	37	60	53	60	2.17	+0.8	11	3,766	n.	36	nw.	4	13	16	2	3.8	0.0	0.0
Rapid City	3,259	50	58	26.67	30.02	+.09	67.5	−2.7	100	14	79	47	11	56	39	59	53	62	4.33	+1.8	15	4,762	w.	34	n.	20	13	13	5	4.4	0.0	0.0
Lander	5,372	60	68	24.74	29.97	+.05	65.5	−1.9	92	14	79	40	12	52	40	53	45	56	2.01	0.0	14	7,658	w.	49	w.	15	12	13	6	4.4	0.0	0.0
Sheridan	3,790	10	47	26.18	30.02	.....	68.0	0.0	94	19	82	42	12	54	42	53	44	48	0.09	−0.8	3	3,778	w.	40	sw.	8	12	18	1	4.3	0.0	0.0
Yellowstone Park	6,200	11	48	24.01	30.02	+.10	66.0	.....	95	19	80	40	17	52	44	57	51	66	2.11	.....	20	3,057	nw.	30	nw.	23	12	16	3	4.4	0.0	0.0
North Platte	2,821	11	51	27.14	30.02	+.09	59.7	−1.8	86	3	74	38	17	45	44	48	41	58	1.45	+0.3	12	4,816	sw.	39	nw.	5	12	12	7	4.5	0.0	0.0
Middle Slope.							72.7	−0.2	98	15	85	48	7	60	36	63	60	71	4.91	+2.2	12	4,346	n.	32	nw.	23	18	6	7	3.8	0.0	0.0
							76.5	**−0.4**										**62**	**3.60**	**+0.6**									**4.4**		
Denver	5,292	106	113	24.84	29.99	+.08	71.8	−0.4	97	15	85	50	11	59	37	56	47	52	1.87	+0.2	12	5,500	s.	38	w.	8	9	19	3	4.6	0.0	0.0
Pueblo	4,685	80	86	25.37	29.95	+.04	74.9	+0.7	101	15	90	53	8	60	45	58	49	51	0.29	−1.7	5	4,828	e.	35	nw.	28	4	23	4	5.5	0.0	0.0
Concordia	1,392	50	58	28.53	29.97	+.02	75.4	−2.7	96	21	86	56	7	65	31	67	63	69	5.82	+2.2	12	5,210	s.	46	nw.	6	9	18	4	4.7	0.0	0.0
Dodge City	2,509	11	51	27.44	29.98	+.05	77.2	−0.5	101	21	90	53	7	65	35	66	61	66	2.86	−0.5	9	7,142	se.	56	nw.	6	19	11	1	2.9	0.0	0.0
Wichita	1,358	139	158	28.55	29.95	−.01	77.5	−1.5	95	23	87	60	4	68	28	70	67	73	8.46	+4.8	9	8,456	s.	68	n.	10	9	17	5	4.5	0.0	0.0
Altus	1,410	5	.....	.....	.....	.....	83.8	.....	108	20	98	56	1	70	42	.....	.....	.....	2.33	.....	4	.....	se.	.....	.....	.....	23	1	7	.....	0.0	0.0
Broken Arrow	765	11	52	29.18	30.00	.....	79.2	.....	97	31	88	58	4	70	24	.....	.....	.....	7.89	.....	8	7,798	s.	40	s.	9	13	9	9	5.0	0.0	0.0
Muskogee	652	4	.....	.....	.....	.....	81.7	.....	103	31	93	58	4	71	28	.....	.....	.....	5.46	.....	6	.....	e.	.....	.....	.....	19	6	6	.....	0.0	0.0
Oklahoma City	1,214	10	47	28.72	29.97	+.01	82.0	+2.2	105	26	93	58	4	71	30	70	66	64	2.31	−1.3	6	7,823	s.	34	s.	10	20	7	4	3.4	0.0	0.0
Southern Slope.							**81.6**	**+1.1**										**50**	**1.25**	**−1.6**									**3.7**		
Abilene	1,738	10	52	28.19	29.95	+.02	84.1	+1.9	103	21	96	62	4	72	30	68	61	52	0.96	−1.4	2	7,224	s.	31	s.	9	13	9	9	4.8	0.0	0.0
Amarillo	3,676	10	49	26.32	29.96	+.04	78.8	+2.7	99	21	92	57	4	66	32	64	56	54	1.04	−2.1	6	7,917	s.	36	n.	6	28	3	0	2.7	0.0	0.0
Del Rio	944	64	71	29.00	29.97	+.07	83.7	−1.0	98	20	93	68	3	74	24	.....	.....	.....	2.84	+0.6	1	7,333	se.	27	s.	24	13	12	6	4.2	0.0	0.0
Roswell	3,566	75	85	26.39	29.91	+.03	79.6	+0.7	102	21	93	58	4	66	34	61	50	43	0.17	−3.3	3	6,065	se.	36	nw.	2	18	13	0	3.0	0.0	0.0
Southern Plateau.							**80.2**	**+1.2**										**41**	**0.72**	**−0.5**									**3.1**		
El Paso	3,762	110	133	26.20	29.85	+.01	81.9	+1.4	101	6	94	63	2	70	33	63	52	42	1.08	−1.0	9	7,545	se.	46	ne.	2	23	8	0	2.4	0.0	0.0
Santa Fe	7,013	38	53	23.40	29.90	+.02	70.2	+1.5	88	5	83	54	1	57	33	54	45	49	1.75	−1.0	10	4,270	e.	28	ne.	16	11	16	4	4.6	0.0	0.0
Flagstaff	6,908	10	59	.....	.....	.....	66.6	+1.6	91	16	82	45	12	52	42	.....	.....	.....	2.28	.....	12	5,455	w.	30	w.	5	14	15	2	.....	0.0	0.0
Phoenix	1,108	11	81	28.69	29.80	+.02	90.6	+0.2	112	5	104	72	18	77	34	70	60	42	0.74	−0.3	7	3,767	w.	44	n.	5	11	15	5	4.6	0.0	0.0
Yuma	141	9	54	29.69	29.83	+.07	91.8	+0.9	112	5	106	71	1	78	36	73	64	45	T.	−0.1	0	4,232	sw.	27	s.	7	25	4	2	2.0	0.0	0.0
Independence	3,957	9	41	26.00	29.94	+.11	80.1	+1.6	103	15	96	57	25	65	39	56	38	27	0.02	−0.1	1	4,099	nw.	32	sc.	18	25	5	1	2.0	0.0	0.0
Middle Plateau.							**74.2**	**+1.5**										**36**	**0.63**	**+0.2**									**3.2**		
Reno	4,532	74	81	25.55	29.96	+.09	73.3	+5.8	100	3	90	44	24	56	43	53	39	37	0.33	+0.2	2	4,990	w.	42	sw.	4	19	10	2	2.5	0.0	0.0
Tonopah	6,090	12	20	24.18	29.96	.....	75.5	.....	98	15	88	53	19	63	29	53	34	27	0.19	0.0	1	3,130	nw.	20	w.	5	17	14	0	3.4	0.0	0.0
Winnemucca	4,344	18	56	25.67	29.98	+.09	71.4	−0.2	99	4	90	44	27	53	47	52	36	36	0.84	+0.5	3	5,570	w.	39	nw.	19	22	7	2	2.4	0.0	0.0
Modena	5,479	10	43	24.70	29.92	+.06	72.1	+2.4	99	14	89	47	1	55	45	52	37	38	1.22	0.0	4	4,444	sw.	38	nw.	4	19	6	6	3.2	0.0	0.0
Salt Lake City	4,360	163	203	25.66	29.94	+.04	76.6	+0.9	98	13	88	58	22	65	33	57	44	37	0.65	+ 0.1	4	4,846	nw.	39	nw.	22	19	9	3	2.9	0.0	0.0
Grand Junction	4,602	60	68	25.42	29.93	+.04	77.7	−1.5	102	15	92	55	12	64	36	58	47	40	0.40	− 0.1	7	4,513	se.	38	sw.	8	13	13	5	4.2	0.0	0.0
Northern Plateau.							**74.1**	**+3.1**										**37**	**0.08**	**− 0.4**									**2.8**		
Baker	3,471	48	53	26.49	30.01	+.06	67.8	+2.8	97	3	84	44	16	51	45	53	41	42	0.01	− 0.4	1	4,314	nw.	20	nw.	7	17	13	1	3.2	0.0	0.0
Boise	2,739	78	86	27.16	29.94	+.01	75.6	+2.8	104	13	91	53	10	60	40	57	42	37	0.19	0.0	1	3,130	nw.	20	w.	19	22	7	2	2.4	0.0	0.0
Lewiston	757	40	48	29.16	29.95	.00	77.8	+4.2	109	3	94	54	21	61	46	.....	.....	.....	0.06	− 0.4	2	2,694	e.	23	nw.	4	20	7	4	2.9	0.0	0.0
Pocatello	4,477	60	68	25.52	29.94	+.02	72.0	+0.8	98	4	87	46	10	57	45	53	38	37	0.17	− 0.5	2	5,785	se.	46	s.	23	15	13	3	3.7	0.0	0.0
Spokane	1,929	101	110	27.95	29.95	−.01	73.2	+4.2	101	3	88	51	11	59	39	55	39	36	0.03	− 0.6	2	4,182	sw.	28	ne.	7	20	10	1	2.6	0.0	0.0
Walla Walla	991	57	65	28.90	29.96	−.01	78.0	+3.9	107	3	91	59	16	65	37	58	43	33	0.04	− 0.4	1	3,643	sw.	19	w.	7	24	6	1	2.0	0.0	0.0
North Pacific Coast region.							**62.2**	**0.0**										**74**	**0.01**	**− 0.7**									**4.6**		
North Head	211	11	56	29.91	30.14	+.06	54.8	−2.9	63	2	58	48	16	52	11	53	52	92	0.03	− 0.5	2	11,206	n.	40	nw.	3	6	14	11	6.2	0.0	0.0
Port Angeles	29	8	53	30.10	30.13	.....	56.8	.....	83	2	65	45	24	48	33	.....	.....	.....	0.00	− 0.4	0	5,244	nw.	25	w.	7	20	8	3	3.5	0.0	0.0
Seattle	125	215	250	29.98	30.11	+.07	62.9	−0.6	87	3	73	48	21	53	29	56	50	69	0.00	− 0.7	0	4,431	nw.	23	sw.	7	18	11	2	3.4	0.0	0.0
Tacoma	213	113	120	29.89	30.11	+.05	63.6	+0.2	90	3	74	48	21	53	30	.....	.....	.....	T.	− 0.7	0	3,645	n.	17	w.	13	0	15	16	7.4	0.0	0.0
Tatoosh Island	86	7	57	30.03	30.13	+.08	53.0	−2.1	66	1	56	48	16	50	16	51	50	94	0.02	− 1.8	2	8,753	s.	39	se.	4	4	4	23	8.0	0.0	0.0
Yakima	1,071	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Medford	1,425	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Portland, Oreg	153	68	106	29.91	30.07	+.02	74.6	.....	108	2	96	44	23	53	53	.....	.....	.....	0.00	.....	0	.....	nw.	.....	.....	.....	23	6	2	.....	0.0	0.0
Roseburg	510	9	57	29.51	30.05	+.02	68.2	+1.5	95	2	80	49	22	57	33	59	52	61	T.	− 0.5	0	4,383	nw.	18	nw.	16	18	10	3	3.0	0.0	0.0
Middle Pacific Coast region.							**71.0**	**+3.6**	**105**	**2**	**89**	**45**	**23**	**54**	**48**	**57**	**47**	**53**	**0.00**	**− 0.3**	**0**	**2,688**	**n.**	**15**	**n.**	**4**	**29**	**2**	**0**	**0.9**	**0.0**	**0.0**
							66.2	**+1.7**										**66**	**T.**	**0.0**									**4.2**		
Eureka	62	73	89	30.02	30.08	+.03	55.1	−0.2	67	2	50	49	15	51	15	52	50	87	0.00	− 0.1	0	4,088	nw.	19	nw.	22	3	9	19	7.6	0.0	0.0
Point Reyes	490	7	18	29.46	29.98	.....	54.7	+1.0	66	11	58	47	28	51	13	.....	.....	.....	0.00	0.0	0	12,646	nw.	50	nw.	24	1	3	27	9.0	0.0	0.0
Red Bluff	332	50	56	29.54	29.88	−.01	83.6	+2.8	112	4	100	58	24	68	37	63	49	37	0.00	0.0	0	3,389	se.	15	se.	10	29	2	0	0.7	0.0	0.0
Sacramento	69	106	117	29.84	29.91	+.03	75.9	+2.7	106	15	92	52	24	60	42	62	55	55	T.	0.0	0	6,592	s.	20	s.	7	30	1	0	0.8	0.0	0.0
San Francisco	155	208	243	29.82	30.00	+.03	60.2	+2.9	74	15	66	50	30	54	20	55	53	83	T.	0.0	0	7,317	sw.	30	w.	22	11	14	6	4.4	0.0	0.0
San Jose	141	12	110	29.83	29.98	.....	68.0	+1.1	94	15	82	45	23	54	41	.....	.....	.....	T.	0.0	0	4,113	nw.	20	nw.	22	24	7	0	2.4	0.0	0.0
South Pacific Coast region.							**71.6**	**+0.9**										**67**	**T.**	**0.0**									**2.6**		
Fresno	327	89	98	29.55	29.89	+.06	83.8	+1.8	108	15	100	56	24	68	38	62	46	33	T.	0.0	0	6,080	nw.	24	nw.	18	28	3	0	0.8	0.0	0.0
Los Angeles	338	159	191	29.61	29.97	+.07	69.5	−0.9	83	15	79	57	27	60	25	62	59	79	T.	0.0	0	3,774	sw.	22	nw.	15	21	8	2	3.0	0.0	0.0
San Diego	87	62	70	29.87	29.96	+.04	67.7	+0.5	76	15	72	60	24	63	13	63	61	82	0.01	0.0	1	4,583	w.	22	w.	17	16	11	4	4.0	0.0	0.0
San Luis Obispo	201	32	40	29.78	30.00	+.05	65.2	+2.0	87	25	77	46	23	53	35	57	52	73	T.	0.0	0	2,823	nw.	16	ne.	25	24	6	1	2.5	0.0	0.0
West Indies.																																	
San Juan, P. R.	82	8	54	29.99	30.08	.....	79.3	.....	86	30	84	72	14	75	12	.....	.....	.....	4.39	− 2.0	24	11,431	e.	32	e.	2	9	18	4	4.7	0.0	0.0
Panama Canal.																																	
Balboa Heights	118	7	97	29.73	29.85	+.01	81.4	+1.0	91	23	88	70	29	75	16	75	74	85	5.08	− 2.5	16	5,609	nw.	30	s.	17	0	16	15	7.4	0.0	0.0
Colon	36	7	97	29.83	29.86	+.01	82.4	+2.2	89	28	87	73	17	78	12	77	76	82	4.40	−11.3	18	8,440	n.	30	n.	25	2	14	15	7.0	0.0	0.0
Alaska.																																	
Juneau	80	11	54	.....	.....	.....	54.0	.....	74	24	60	41	21	48	26	51	49	83	3.16	.....	19	3,675	s.	23	nw.	9	5	1	25	8.2	0.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, July, 1922.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48												
Halifax, N. S.	88												
Yarmouth, N. S.	65												
Charlottetown, P. E. I.	38												
Chatham, N. B.	28												
Father Point, Que.	20	29.92	29.94	+0.09	56.7	−0.9	67.7	45.7	81	38	1.37	−1.67	0.0
Quebec, Que.	296	29.67	29.99	+ .08	67.5	+2.0	78.2	56.8	86	45	2.30	−1.96	0.0
Montreal, Que.	187	29.77	29.97	+ .04	69.2	+0.7	77.9	60.6	86	51	2.69	−1.60	0.0
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.73	29.99	+ .05	69.5	0.0	81.0	58.0	88	49	1.89	−1.58	0.0
Kingston, Ont.	285	29.69	29.99	+ .02	68.7	+0.5	76.0	61.5	83	52	3.20	+0.31	0.0
Toronto, Ont.	379	29.60	29.99	+ .02	69.5	+1.5	79.9	59.2	87	50	2.99	+0.07	0.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.64	29.93	− .01	58.4	−1.1	73.8	43.0	82	24	2.46	−0.34	0.0
Port Stanley, Ont.	592	29.40	30.03	+ .05	67.0	−0.8	76.6	57.5	81	46	3.78	+0.74	0.0
Southampton, Ont.	656	29.30			64.1	−0.6	73.3	54.8	85	42	6.58	+4.60	0.0
Parry Sound, Ont.	688	29.30	29.98	+ .02	66.5	+0.5	76.7	56.3	87	44	5.19	+2.57	0.0
Port Arthur, Ont.	644	29.26	29.97	+ .03	61.5	−0.5	71.0	52.0	81	41	4.06	+0.58	0.0
Winnipeg, Man.	760	29.10	29.91	− .02	66.2	+0.2	77.7	54.7	89	41	4.95	+1.87	0.0
Minnedosa, Man.	1,690	28.15	29.93	.00	62.8	+0.6	75.2	50.5	88	41	1.17	+1.43	0.0
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.72	29.93	+ .01	62.5	−1.0	76.0	49.0	89	38	1.51	−0.97	0.0
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.43	30.01	+ .10	63.9	−2.6	78.7	49.1	92	38	1.05	−1.39	0.0
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150	27.68	29.92	+ .02	62.7	+2.1	77.7	47.8	88	39	1.73	−1.30	0.0
Prince Albert, Sask.	1,450	28.39	29.94	+ .03	63.6	+1.7	76.7	50.5	89	42	0.54	−1.51	0.0
Battleford, Sask.	1,562	28.21	29.92	+ .02	64.7	0.0	80.6	48.8	89	38	0.22	−2.12	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230												
Barkerville, B. C.	4,180												
LATE REPORTS, JUNE, 1922.													
St. Johns, N. F.	125	29.74	29.88	− .03	54.8	+3.2	63.5	46.1	78	35	3.23	−0.37	0.0
Edmonton, Alb.	2,150	27.62	29.86	+ .02	59.0	+2.1	73.7	44.4	90	28	1.09	−1.77	0.4
Hamilton, Ber.	151	30.02	30.18	+ .06	73.6	−1.4	79.5	67.7	85	63	10.26	+4.31	0.0

SEISMOLOGICAL REPORTS FOR JULY, 1922.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, September 3, 1922.]

TABLE 1.—*Noninstrumental earthquake reports, July, 1922.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1921.	*H. m.*		° ′	° ′			*Sec.*			
July 5	19 00	Los Alamos	34 45	120 15	3	1	.....	Yes	.....	H. R. Geve.
9	12 00	.....do.....	34 45	120 15	3	1	.....	.....	.....	Do.
11	5 00	.....do.....	34 45	120 15	3	1	.....	.....	.....	Do.
	15 30	.....do.....	34 45	120 15	3	1	.....	.....	.....	Do.
		MAINE.								
2	21 26	Wytopitlock	45 40	68 05	3?	2	16 *ca*	None	Felt by several	D. E. Huff.
		OREGON.								
5	18 06	Portland	45 30	122 40	3	1	15	None	Felt by several	A. J. Neylon; Margaret Simonson.
		WASHINGTON.								
5	18 05	Stabler	45 50	122 00	4	1	20	None	Felt by several	J. V. Hofman; H. V. Brown.
		WISCONSIN.								
7	.....	Fond du Lac	43 50	88 30	.....	.....	.....	.....	Gas mains broken	Press report.

LATE REPORTS.

		ARIZONA.								
June 15	13 40	Yuma	32 40	114 35	4	3	.....	None	Shocks at 14:30 and 15:20	J. H. Gordon.
16	21 01	.....do.....	32 40	114 35	5	5	10–20	Rumbling	Shock at 21:25	Do.
17	23 30	Natural Bridge	.....	.....	4?	1	.....	Loud	Felt by many	D. G. Goodfellowe.
	23 42	Payson	34 10	111 00	4	1	60	Rumbling	.....do.....	Mrs. R. C. James.
		Roosevelt	33 40	111 00	4	1	5–10	.....do.....	.....do.....	F. W. Croxen.
		Young	34 05	111 00	5?	2	3–4	.....do.....	.....do.....	G. B. Rencher.

TABLE 2.—*Instrumental seismological reports, July, 1922.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols and description of stations, see REVIEW for January, 1922.]

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2	.....	e_E	13 39 21	.....	.....	.....	.....	e phases poorly defined; S may be L.
		e_E	13 43 23	.....	.....	.....	.....	
		S_E	13 45 13	.....	.....	.....	.....	
		L_E	13 47 21	14	.....	.....	.....	
		M_E	13 47 21	13	*10	.....	.....	
		F_E	14 09 ..	.....	.....	.....	.....	

* Trace amplitude.

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2	.....	eP_E..	13 42 53	.....	.....	.....	.....	P phases doubtful: end portion lost in changing traces. No definite M.
		$ePR1_E$	13 45 26	.....	.....	.....	.....	
		$ePR1_N$	13 45 00	.....	.....	.....	.....	
		S.....	13 49 59	4	.....	.....	.....	
		$SR1_E$.	13 53 31	.....	.....	.....	.....	
		$SR1_N$.	13 53 20	.....	.....	.....	.....	
		L_E....	13 59 ..	18	*10	.....	.....	
		L_N....	13 57 ..	.....	.....	.....	.....	

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2	.....	.....	.....	.....	50	50	.....	Tremors during preceding 24 hours.
12	.....	.....	.....	.....	100	100	.....	
15	.....	.....	.....	.....	50	50	.....	
20	.....	.....	.....	.....	50	100	.....	
24	.....	.....	.....	.....	50	50	.....	
30	.....	.....	.....	.....	100	100	.....	
31	.....	.....	.....	.....	100	100	.....	

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2	.....	P.....	13 46 25	.....	.....	.....	6,300	
		S.....	13 54 18	.....	.....	.....	.....	
		L.....	14 03 20	.....	.....	.....	.....	
		F.....	15 *ca.*	.....	.....	.....	.....	
2	.....	e.....	21 28 53	.....	.....	.....	.....	
		F.....	21 33 *ca.*	.....	.....	.....	.....	
10	.....	e.....	9 55 ..	.....	.....	.....	.....	
		F.....	10 *ca.*	.....	.....	.....	.....	
26	.....	e.....	6 44[illegible]00	.....	.....	.....	.....	
		F.....	6 50 *ca.*	.....	.....	[illegible]	.....	

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
July 2	.....	O.....	13 35 47	.....	.....	.....	3,580	$SR1_E$ characteristic of L.
		P_E....	13 42 45	.....	.....	.....	.....	
		P_N....	13 42 34	.....	.....	.....	.....	
		S.....	13 47 55	.....	.....	.....	.....	
		SR1...	13 49 49	18	.....	.....	.....	
		L.....	13 51 01	11	.....	.....	.....	
		M.....	13 53 47	10	175	140	.....	
		F_E....	15 51 ..	.....	.....	.....	.....	
		F_N....	15 42 ..	.....	.....	.....	.....	
5	.....	e_E.....	18 50 45	.....	.....	.....	.....	
		e_N.....	18 51 00	.....	.....	.....	.....	
		M.....	18 53 23	9	19	15	.....	
		F_E....	19 06 ..	.....	.....	.....	.....	
		F_N....	19 03 ..	.....	.....	.....	.....	
13	.....	e.....	5 19 ..	.....	.....	.....	.....	Poorly defined.
		F.....	6 01 ..	.....	.....	.....	.....	
29	.....	e_E.....	20 24 15	15	10	.....	.....	
		e_N.....	20 24 ..	.....	.....	.....	.....	
		F_E....	20 33 ..	.....	.....	.....	.....	
		F_N....	20 30 ..	.....	.....	.....	.....	

Period of pendulums, 12 sec.; multiplication, 150. Sensitivity before July 15, N, 28.9; E, 21.8; after July 15, N, 28.7; E, 25.3.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
July 2	.....	iP.....	13 44 39	.....	.....	.....	5,200	
		S.....	13 51 31	.....	.....	.....	.....	
		L.....	13 58 44	30	.....	.....	.....	
		M.....	14 05 30	.....	*1,500	.....	.....	
		F.....	17 30 *ca.*	.....	.....	.....	.....	
2	.....	e.....	21 30 25	.....	.....	.....	.....	No distinct phases.
		F.....	21 37 *ca.*	.....	.....	.....	.....	
5	.....	e.....	18 51 20	.....	.....	.....	.....	
		L.....	19 03 50	18	.....	.....	.....	
		F.....	19 50 *ca.*	.....	.....	.....	.....	
10	.....	P.....	9 47 45	.....	.....	.....	6,200	L not in evidence.
		S.....	9 55 32	.....	.....	.....	.....	
		SR1...	9 59 03	.....	.....	.....	.....	
		F.....	10 30 *ca.*	.....	.....	.....	.....	
13	.....	e.....	5 25 00	.....	.....	.....	.....	
		L.....	5 53 ..	22	.....	.....	.....	
		L.....	6 15 20	18	.....	.....	.....	
		F.....	6 50 *ca.*	.....	.....	.....	.....	
26	.....	e.....	6 42 15	.....	.....	.....	.....	
		F.....	7 *ca.*	.....	.....	.....	.....	

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1922.			H. m. s.	Sec.	μ	μ	Km.
July 2	.....	e.....	21 28 36	3	.....	.....	.....
		M.....	21 29 35	3	*10	*10	.....
		F.....	21 30 52	.....	.....	.....	.....

* Trace amplitude.

CANAL ZONE. *Panama Canal, Balboa Heights.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
July 6	.....	.....	.....	.....	.....	.....	.....	Very slight disturbance, 6:04:18 to 6:06:00; distance and direction unknown.
10	.....	.....	.....	.....	.....	.....	.....	Very slight disturbance, 3:41 to 3:44; distance and direction unknown.
12	.....	.....	.....	.....	.....	.....	.....	Very slight disturbance, 9:14 to 9:17; distance and direction unknown.

VERMONT. *U. S. Weather Bureau, Northfield.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
July 2	.....	e.....	13 50 15	.....	.....	.....	.....	
		eL.....	14 05 ..	.....	.....	.....	.....	
		F.....	14 25 *ca.*	.....	.....	.....	.....	
10	.....	e.....	9 54 ..	.....	.....	.....	.....	
		F.....	9 58 ..	.....	.....	.....	.....	

LATE REPORTS (INSTRUMENTAL).

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
May 4	.....	e_E.....	9 25 30	.....	.....	.....	.....	Micros.
		e_N.....	9 25 25	.....	.....	.....	.....	
		S_E....	9 35 45	.....	.....	.....	.....	
		L_E....	10 02 ..	.....	.....	.....	.....	
		L_N....	10 07 ..	.....	.....	.....	.....	
		F.....	11 13 ..	.....	.....	.....	.....	
10	.....	e.....	23 13 ..	.....	.....	.....	.....	Very heavy micros.
		eL_N...	23 20 ..	.....	.....	.....	.....	
		F.....	23 30 ..	.....	.....	.....	.....	
11	.....	e_E.....	1 08 22	.....	.....	.....	.....	Micros.
		e_N.....	1 09 ..	.....	.....	.....	.....	
		F.....	1 20 ..	.....	.....	.....	.....	
11	.....	eP_E...	6 52 00	.....	.....	.....	.....	Heavy micros.
		iP_N...	6 52 00	.....	.....	.....	.....	
		S_E?...	6 57 15	.....	.....	.....	.....	
		S_N?...	6 57 10	.....	.....	.....	.....	
		eL_E...	7 04 18	20	.....	.....	.....	
		eL_N...	7 04 18	.....	.....	.....	.....	
		F.....	7 20 *ca.*	.....	.....	.....	.....	
12	.....	S_E?...	19 12 10	.....	.....	.....	.....	
		eL_E?..	19 40 33	24	.....	.....	.....	
		L_N....	19 43 23	19	.....	.....	.....	
		L_E....	19 45 ..	19	.....	.....	.....	
		F.....	19 55 ..	.....	.....	.....	.....	

Observations were temporarily discontinued at the following stations:

Colorado. Regis College, Denver.

New York. Fordham University, New York.

No reports for July, 1922, have been received from the following stations:

Alabama. Spring Hill College, Mobile.

District of Columbia. Georgetown University, Washington.

Massachusetts. Harvard University, Cambridge.

Missouri. St. Louis University, St. Louis.

New York. Cornell University, Ithaca.

Porto Rico. U. S. C. & G. S. Magnetic Observatory, Vieques.

Canada. Dominion Observatory, Ottawa; Dominion Meteorological Service, Toronto *and* Victoria.

Chart I. Tracks of Centers of Anticyclones, July, 1922. (Inset) Departure of Monthly Mean Pressure from Normal.
(Plotted by Wilfred P. Day.)

Chart I. Tracks of Centers of Anticyclones, July, 1922. (Inset) Departure of Monthly Mean Pressure from Normal.

(Plotted by Wilfred P. Day.)

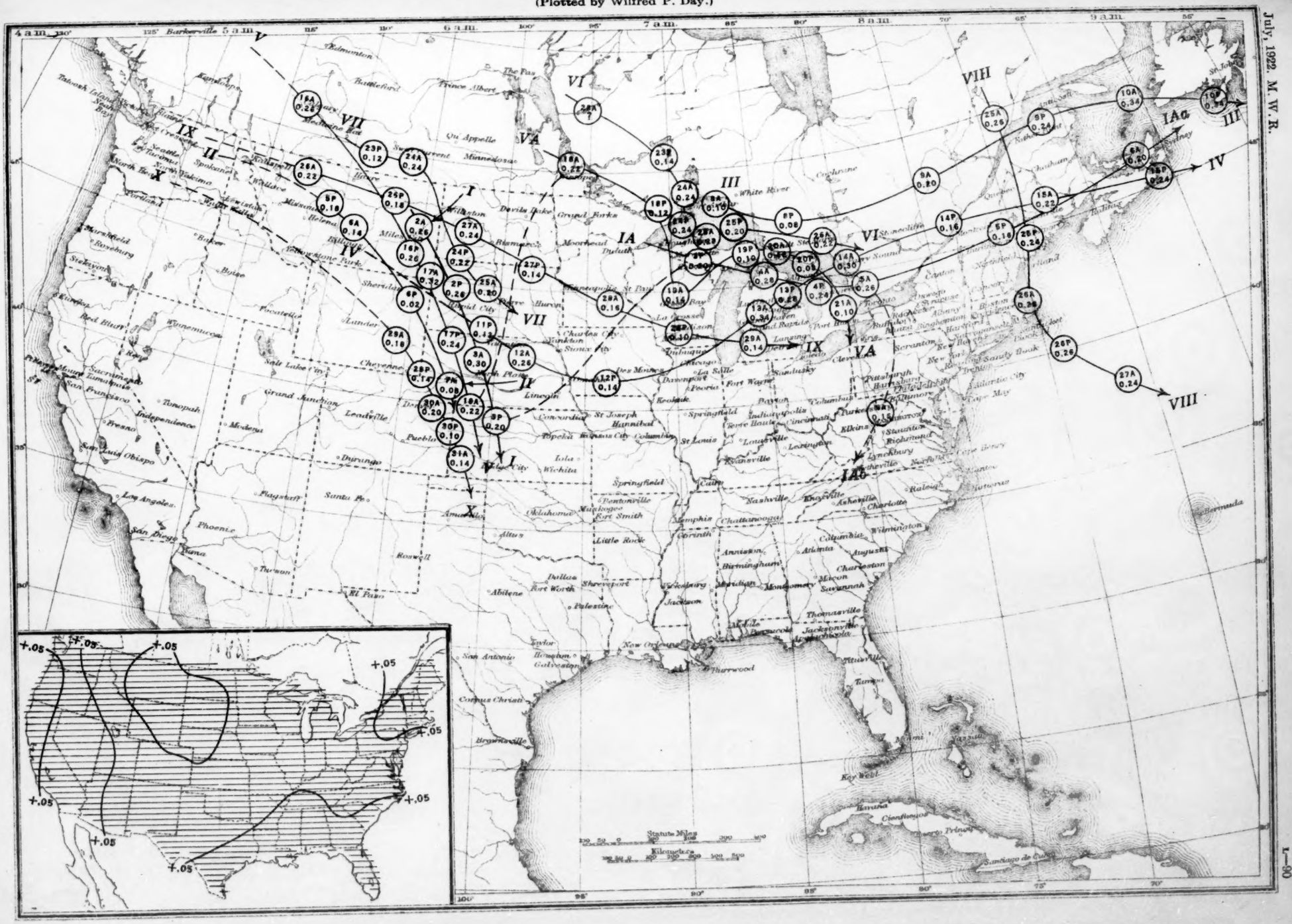


Chart II. Tracks of Centers of Cyclones, July, 1922. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)

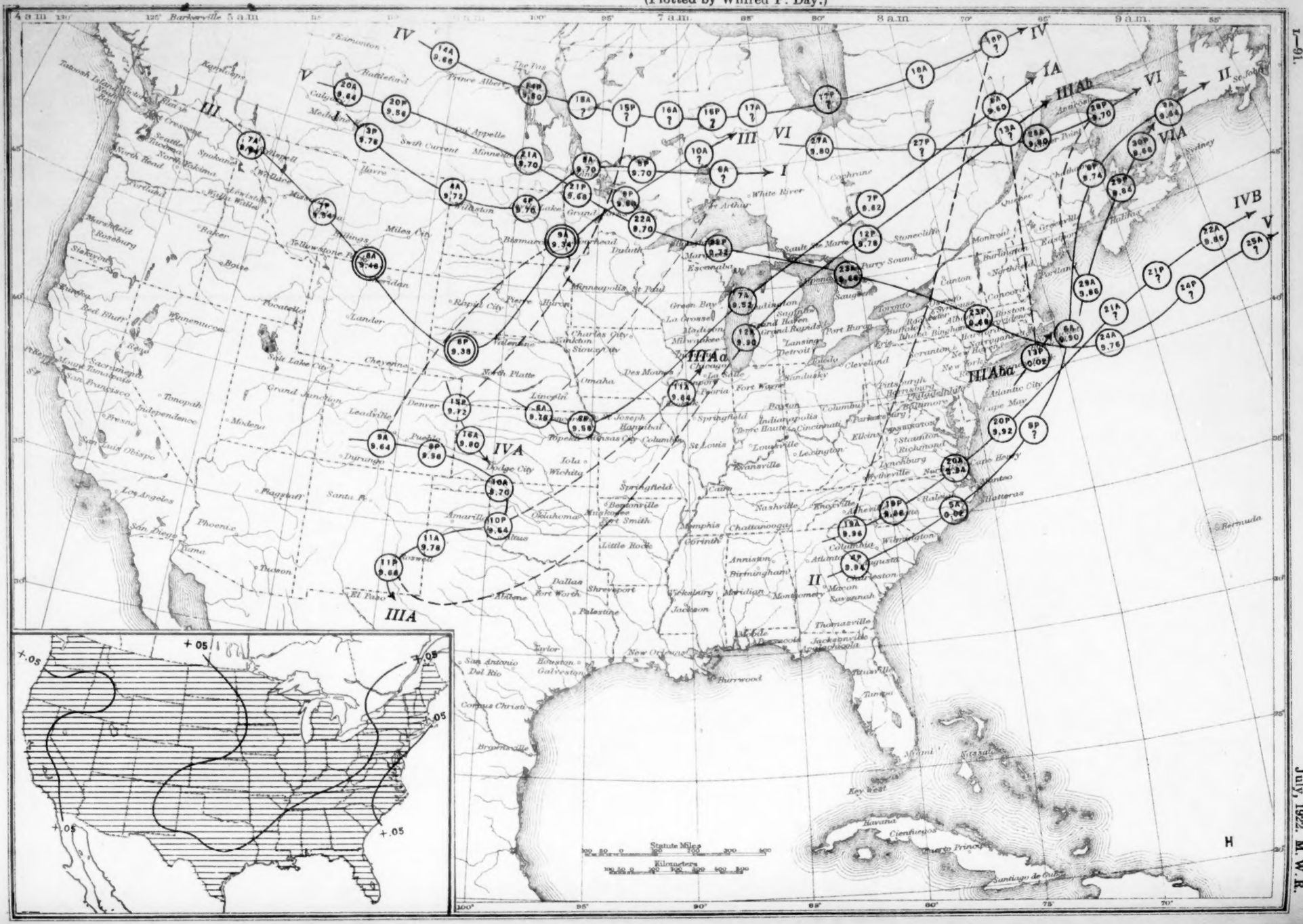


Chart III. Departure (°F.) of the Mean Temperature from the Normal, July, 1922.

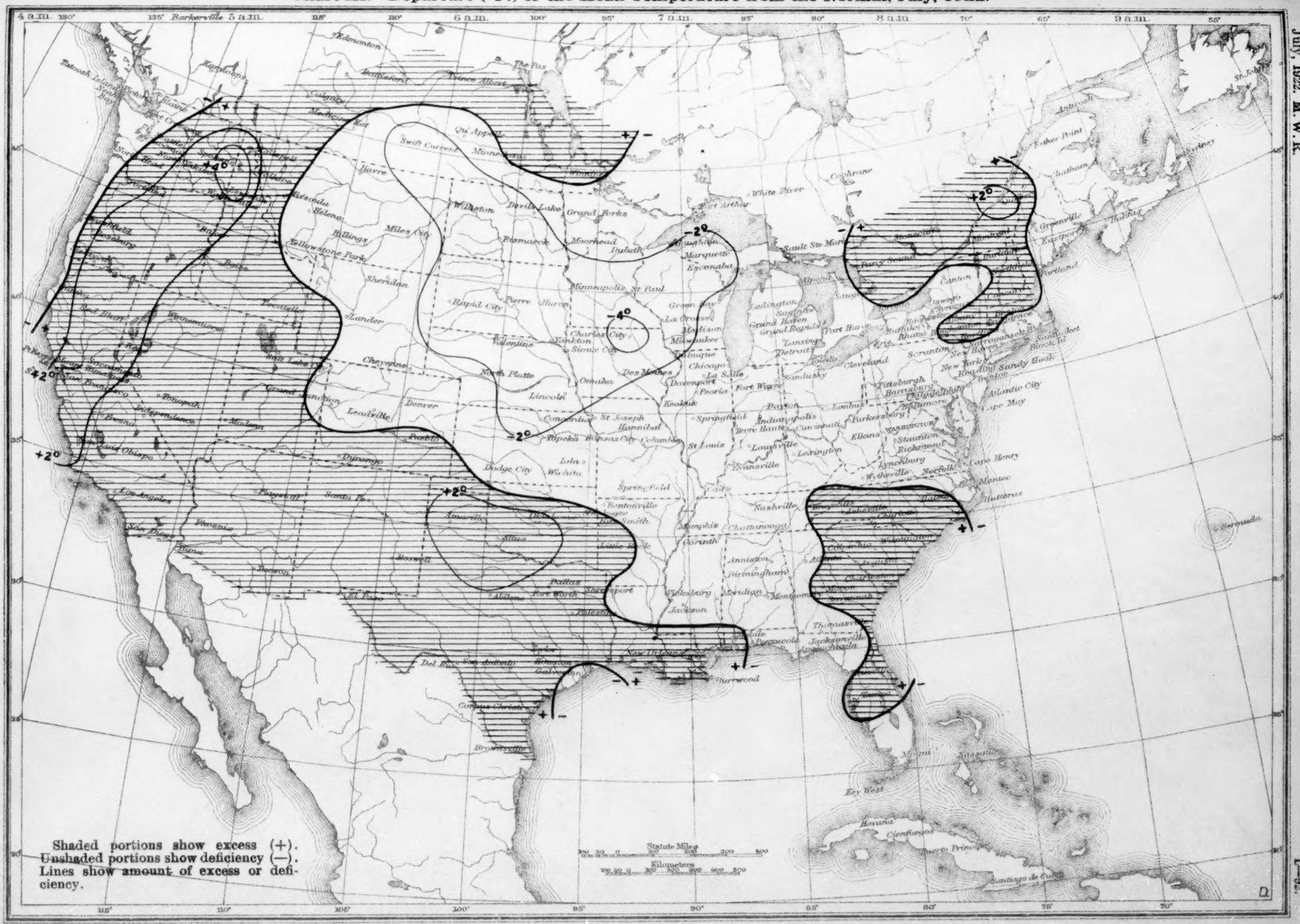

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart IV. Total Precipitation, Inches, July, 1922. (Inset) Departure of Precipitation from Normal.

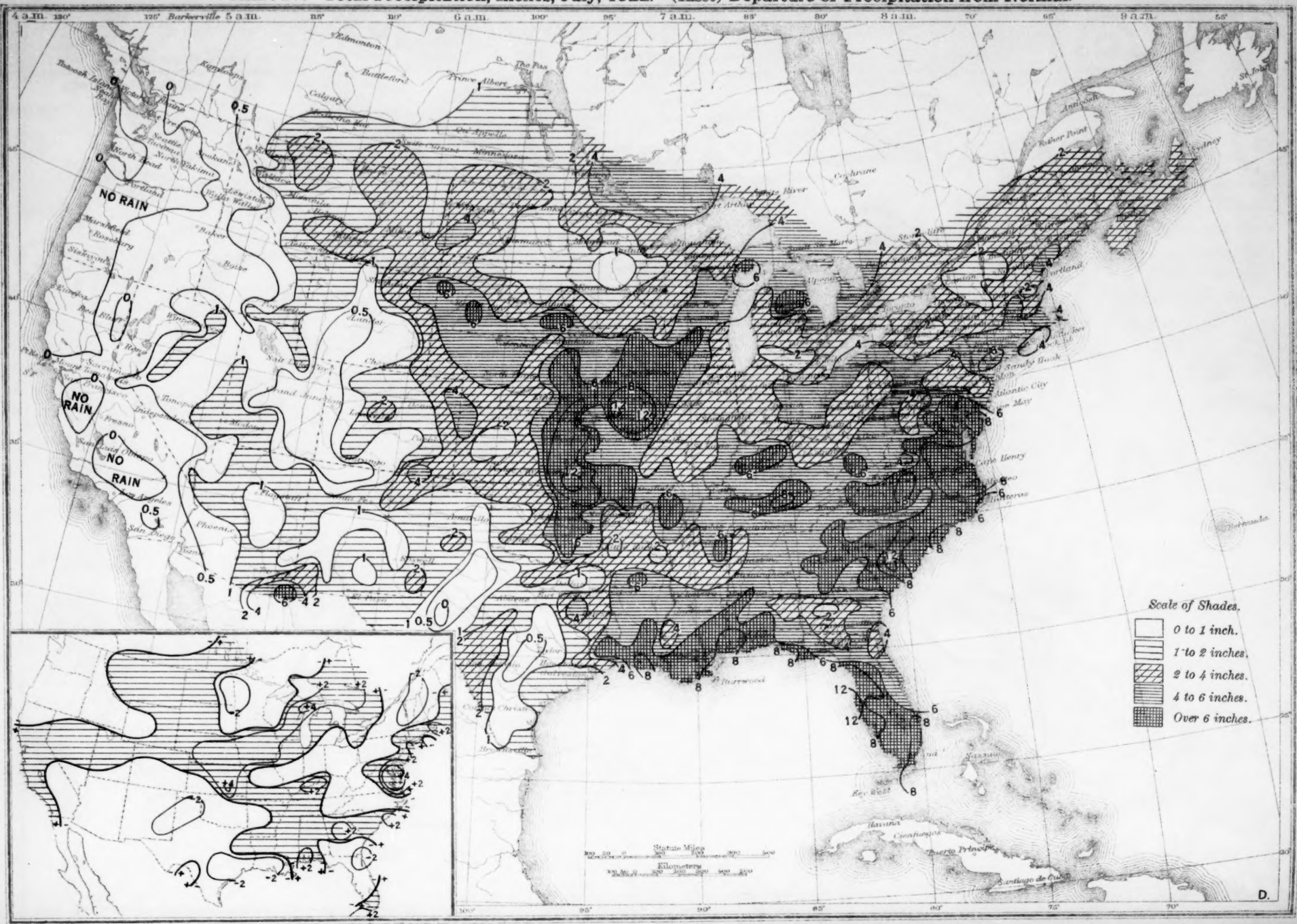


Chart V. Percentage of Clear Sky between Sunrise and Sunset, July, 1922.

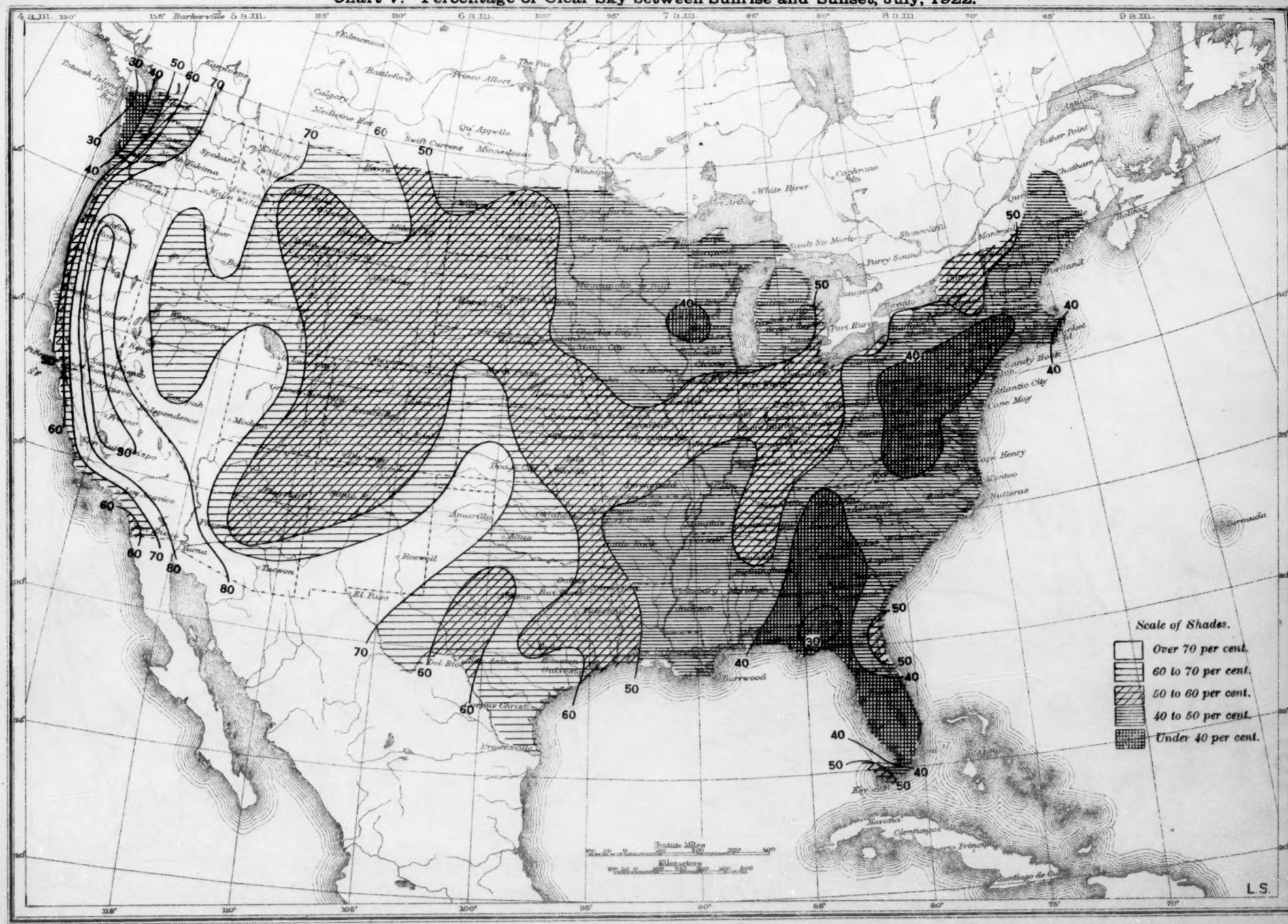


Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, July, 1922.

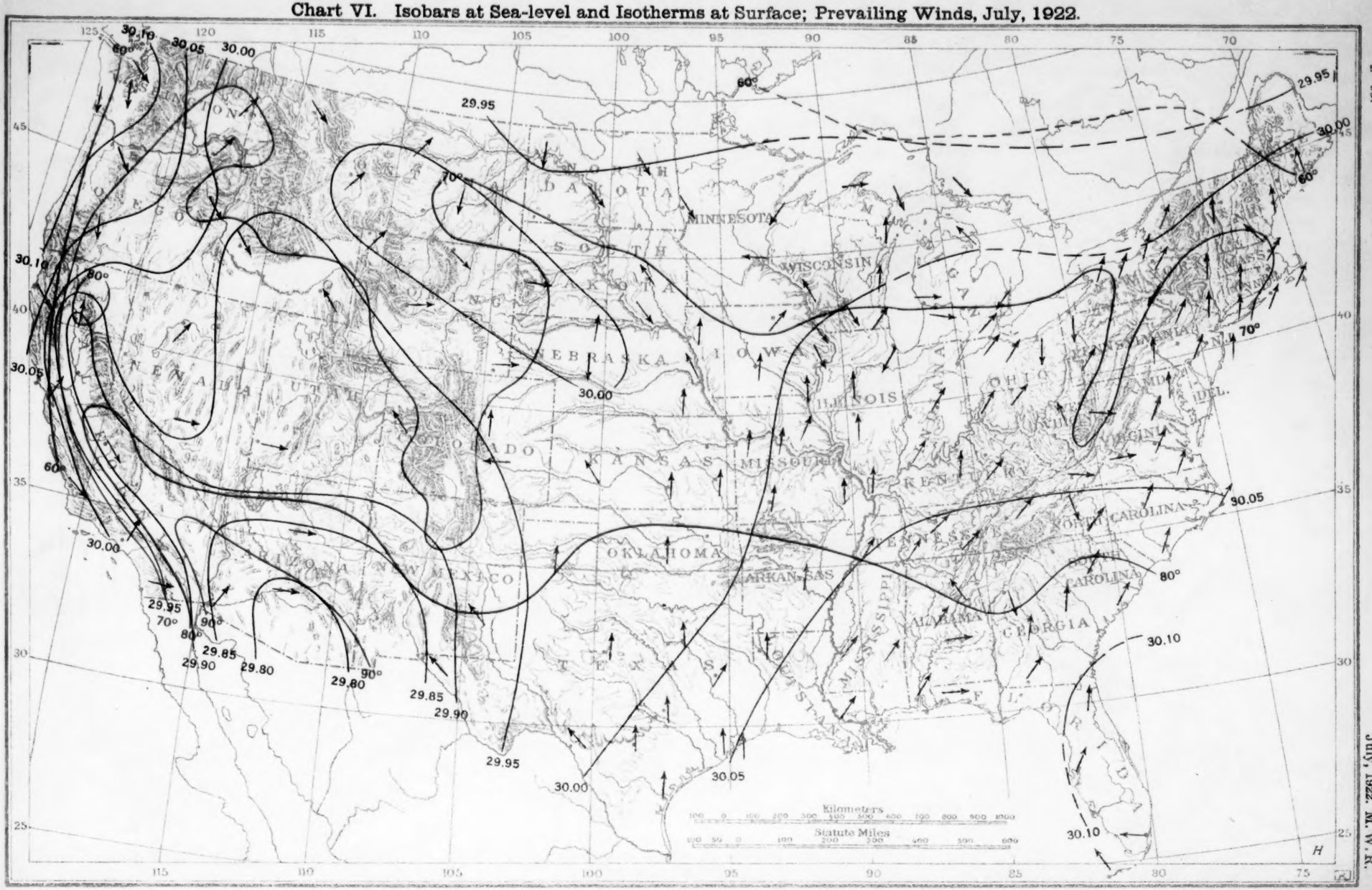


Chart VIII. Weather Map of North Atlantic Ocean, July 6, 1922.

Chart VIII. Weather Map of North Atlantic Ocean, July 6, 1922.

(Plotted by F. A. Young.)

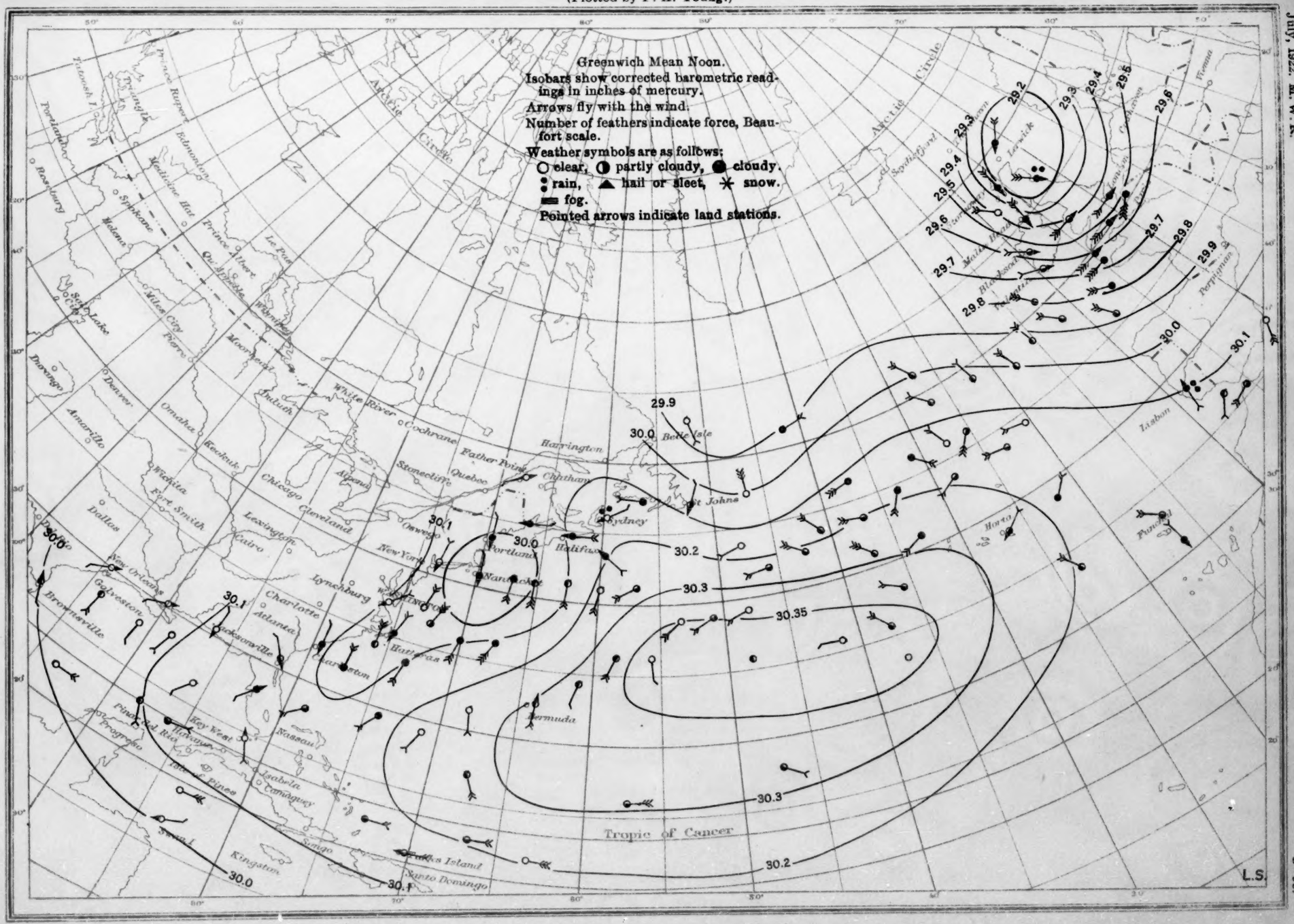
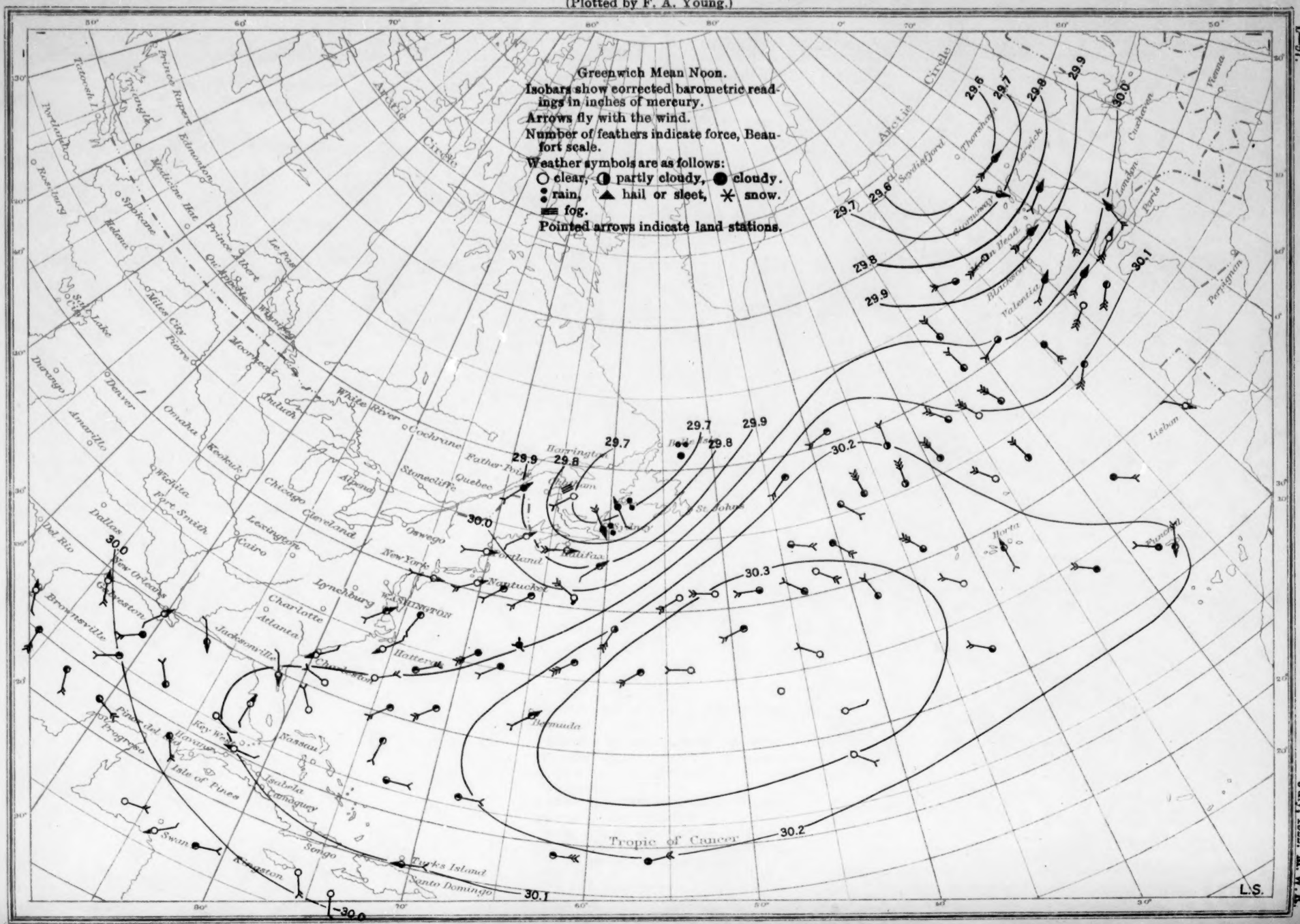


Chart IX. Weather Map of North Atlantic Ocean, July 7, 1922.

(Plotted by F. A. Young.)



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July, 1922. M. W. R.

Chart X. Weather Map of North Atlantic Ocean, July 8, 1922.

(Plotted by F. A. Young.)

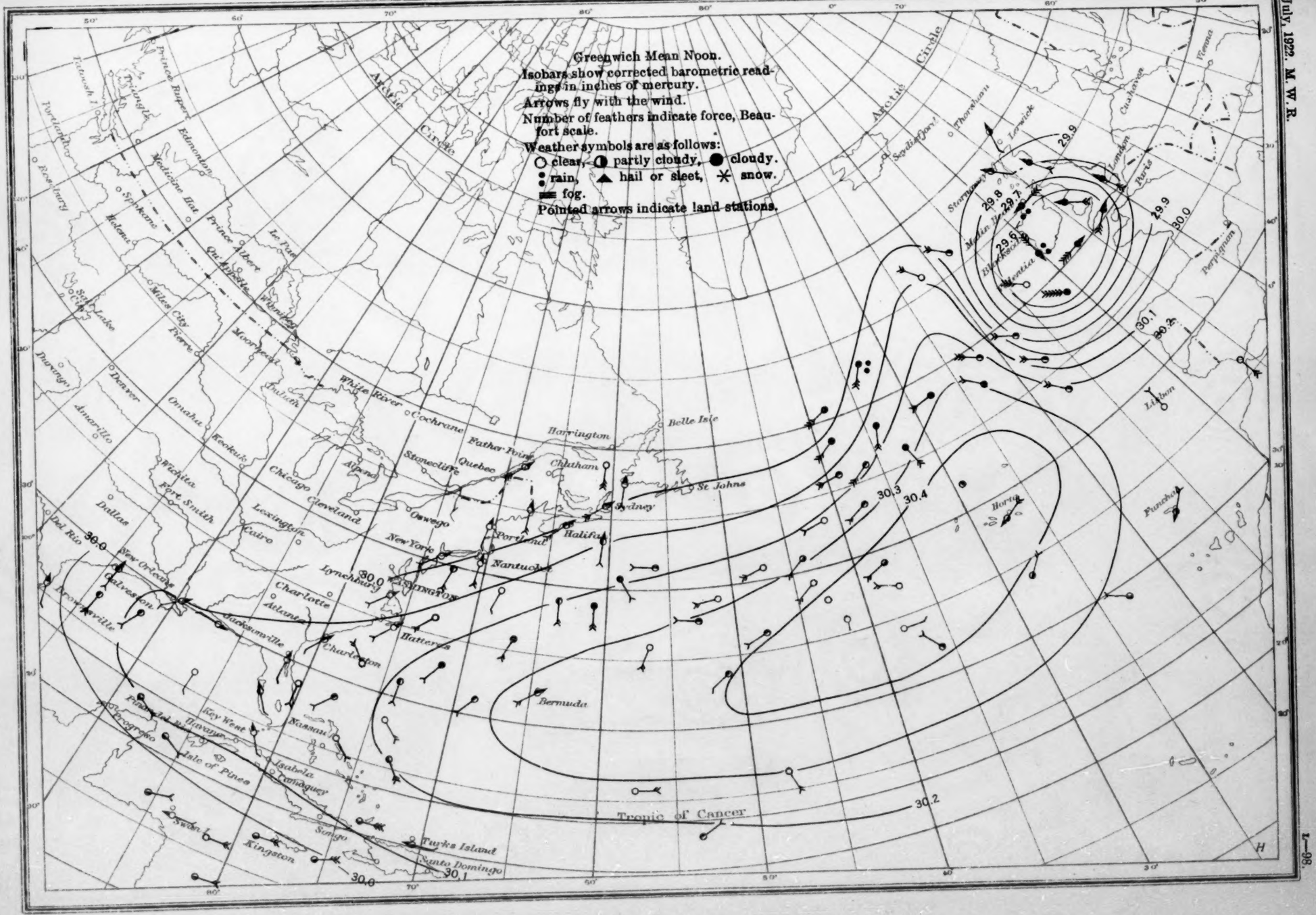
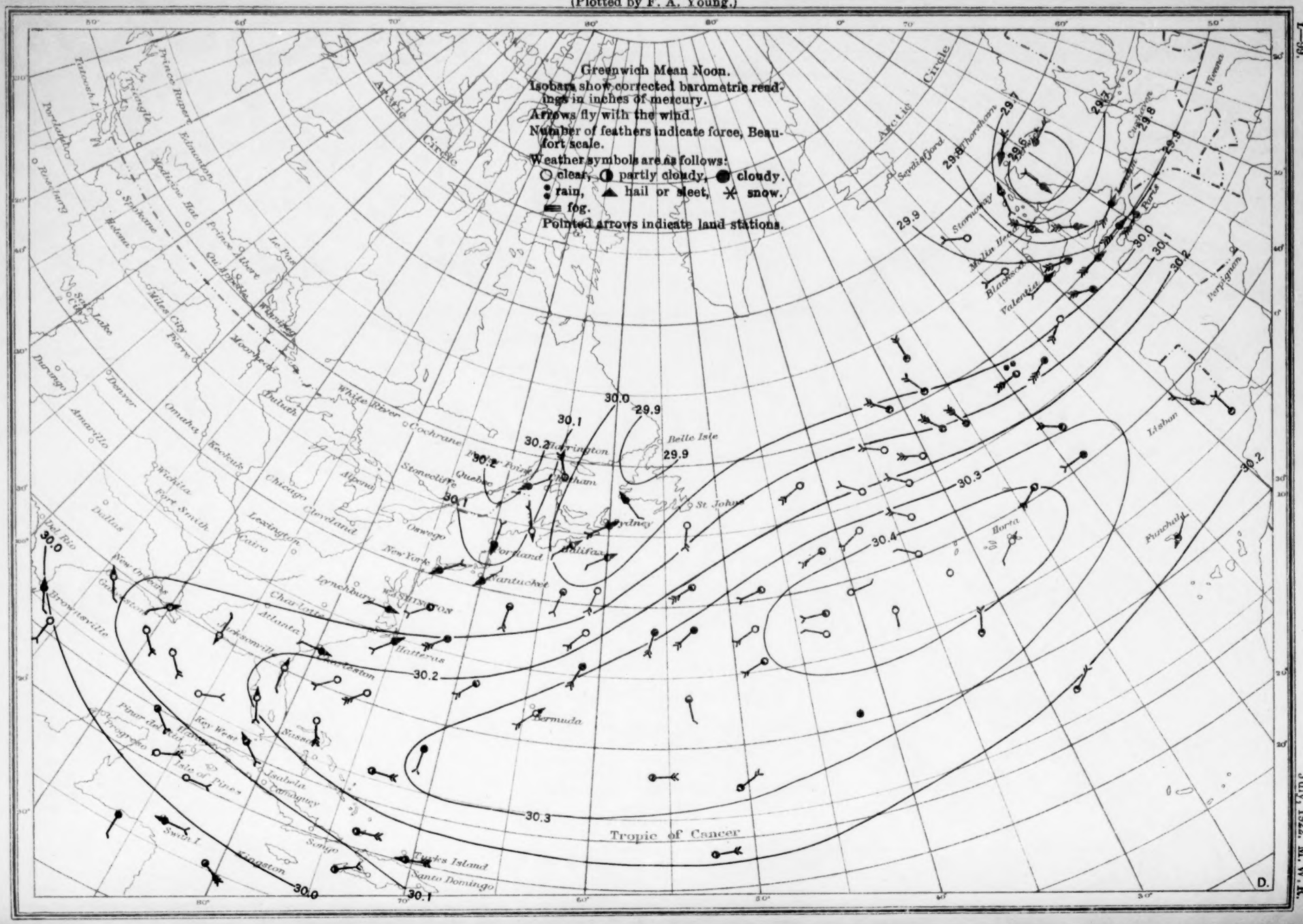


Chart XI. Weather Map of North Atlantic Ocean, July 9, 1922.

(Plotted by F. A. Young.)



L—99.

July, 1922. M. W. R.

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